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CORRECTION

Volume 54, page 401 (September, 1926), first column, line 24 should read "to the crest of 25.9 feet, 5.9 feet above the flood stage, at", and the sentence beginning in line 34 should read "The stage of 29.6 at LeRoy is a record stage at that station." In the table on page 403, first column, the crest stage at Emporia should read 25.9.

UNIV. OF MICH.

(To face p. 127)

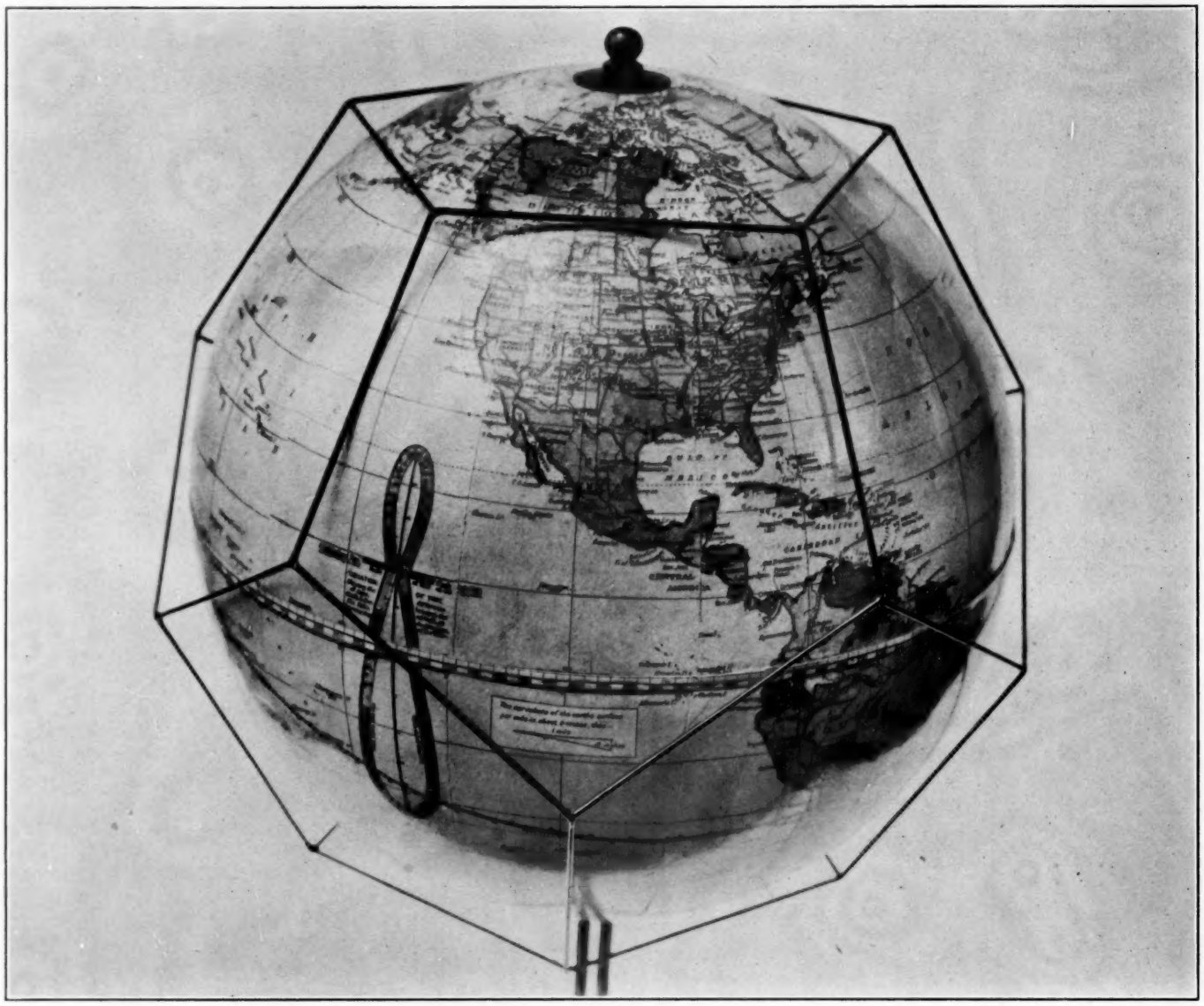

FIGURE 1.—Photographic reproduction of dodecahedral projection world map

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PROJECTIONS FOR WORLD MAPS

By C. F. MARVIN AND OTHERS

I have been greatly interested in examining the two projections here presented and discussed in the papers immediately following.

If the meridional lines in Goode's projections be examined it will be noticed that some of them have a decided curvature, with convexity in both left hand and right hand directions. This, it seems to me, for the depicting of isobaric configurations, is especially unfortunate and causes a type of distortion that misrepresents pressure distribution. These considerations lead me to express the hope that cartographers will develop the conformal projection of the dodecahedron, which permits of presentation on flat surfaces with decidedly less distortion than in either of the two projections described, although, here again, disadvantages may be pointed out. Possibly it is a question whether any one map projection can be used to meet the needs of meteorologists for analysis of atmospheric conditions over the entire globe. I believe, however, that the dodecahedral projection, combined with the Mercator projection for areas immediately contiguous to the Equator, presents decidedly the best cartographic representations of the earth's surface that are practical for meteorological purposes. In Figure 1 frontispiece is shown a photographic perspective of a globe inclosed by a skeleton frame representing a secant dodecahedron, each of the pentagonal surfaces of which has an area exactly equal to one-twelfth of the globe. In Figure 2 is shown one of several possible developments of the dodecahedron, with geographic areas sketched in rudely. The great merit of a projection of this character is that it provides adequate conformal projection of all terrestrial surfaces, especially within the polar regions.

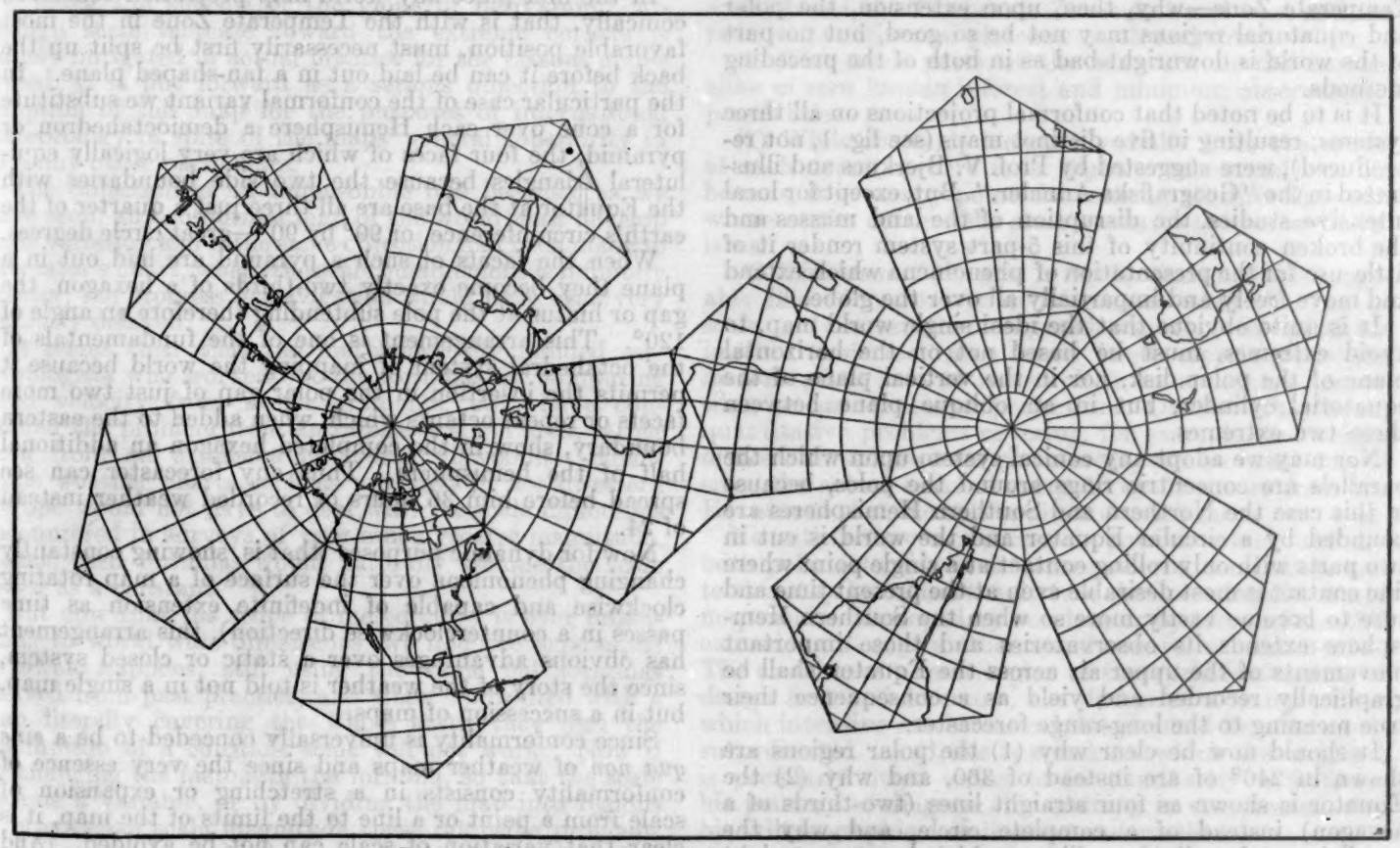


FIGURE 2.—Crude development of dodecahedral projection for world maps

The distortion in form of equal-area maps makes them more or less impossible for meteorological problems involving questions of the dynamics of the atmospheric circulation, whereas on the dodecahedral configuration, the isobaric distributions are almost exact for all parts of the map.

PROJECTIONS FOR WORLD MAPS [1]

By B. J. S. CAHILL, F. R. G. S., Architect

[Webster Block, Oakland, Calif., May 1, 1929]

The Conformal Variant of The Butterfly Map of the World [2] is now, after 25 years' study, perfected for the use of meteorologists. The author firmly believes that no better world map is possible for this purpose.

In designing a world map projection, as in designing a building, a just compromise must be harmoniously arrived at between various conflicting demands so that the more insistent shall prevail over the less insistent. Thus a disk on top of each pole would yield the maximum of arctic accuracy.

But if this disk is expanded to cover the hemisphere the Temperate Zones will not be so good and the equatorial regions will be worse. On the other hand, a cylindrical belt around the equatorial regions yields the maximum accuracy for the Torrid Zone. But if this belt be extended, the temperate regions are now not so good and the polar regions bad. Whereas, if, as in this map, we conceive the world projected conically—that is, from the Temperate Zone—why, then, upon extension, the polar and equatorial regions may not be so good, but no part of the world is downright bad as in both of the preceding methods.

It is to be noted that conformal projections on all three systems, resulting in five distinct maps (see fig. 1, not reproduced), were suggested by Prof. V. Bjerknes and illustrated in the "Geografiska Annaler." But, except for local intensive studies, the disruption of the land masses and the broken continuity of this 5-part system render it of little use for the presentation of phenomena which extend and move freely and impartially all over the globe.

It is quite obvious that the ideal single world map, to avoid extremes, must be based not on the horizontal plane of the polar disk, nor in the vertical plane of the equatorial cylinder, but in an oblique plane between these two extremes.

Nor may we adopt any conical system upon which the parallels are concentric rings around the poles, because in this case the Northern and Southern Hemispheres are bounded by a circular Equator and the world is cut in two parts with only rolling contact at a single point where line contact is most desirable even at the present time and sure to become vastly more so when the Southern Hemisphere extends its observatories and those important movements of the upper air across the Equator shall be graphically recorded and yield as a consequence their true meaning to the long-range forecaster.

It should now be clear why (1) the polar regions are shown in 240° of arc instead of 360, and why (2) the Equator is shown as four straight lines (two-thirds of a hexagon) instead of a complete circle, and why the parallels are interlinking ellipses which become straight lines at the Equator.

It must be remembered that this map is deliberately designed to be the most accurate possible of the whole world on a single diagram, and to this end it is planned around the actual contours of the earth so as to encompass the pattern of the continents and adjacent seas in the closest fitting frame possible. It is obvious that the human world spreads east and west in the Northern Hemisphere (if we include the great belts of transoceanic intercommunication). This, the main body of the map, takes in by far the major part of the earth's anthropogeographical interest. There remain the three land peninsulas radiating from the major mass and the island groups of the South Pacific. While the four southern octants can be arranged in a two-thirds hexagon exactly like the northern mass, when these are added one by one to the northern group to complete the radiating land extensions of South Africa, South America, Australia, and New Zealand they necessarily become separated. But considering the enormous disparity between the human importance of the northern nucleus compared to the southern streamers, this arrangement of the butterfly map in its discontinuous aspect is not only a fair price to pay for the great accuracy achieved by this sacrifice but it presents a logical pictorial expression of the world's ground plan, the home of the human race—a grand central Temperate Zone pavilion with four subordinate radiating wings which extend across the Equator toward the South Pole.

Let us now consider in detail to what precise extent the polar and equatorial regions of the butterfly map are not so good for the purposes of the meteorologists.

In the first place any world-map projection conceived conically, that is with the Temperate Zone in the most favorable position, must necessarily first be split up the back before it can be laid out in a fan-shaped plane. In the particular case of the conformal variant we substitute for a cone over each Hemisphere a demioctahedron or pyramid, the four faces of which are very logically equilateral triangles because the two side boundaries with the Equator at the base are all three just a quarter of the earth's circumference, or 90° by 90°—great circle degrees.

When the facets of such a pyramid are laid out in a plane they become exactly two-thirds of a hexagon, the gap or hiatus at the pole subtending therefore an angle of 120°. This arrangement is one of the fundamentals of the octahedral system of mapping the world because it permits the insertion in the polar gap of just two more facets or repeat octants which, when added to the eastern boundary, show in the completed hexagon an additional half of the hemisphere. Thus any forecaster can see spread before him 36 hours of recorded weather instead of 24.

Now for dynamic purposes (that is, showing constantly changing phenomena over the surface of a map rotating clockwise and capable of indefinite extension as time passes in a counterclockwise direction), this arrangement has obvious advantages over a static or closed system, since the story of the weather is told not in a single map, but in a succession of maps.

Since conformality is universally conceded to be a *sine qua non* of weather maps and since the very essence of conformality consists in a stretching or expansion of scale from a point or a line to the limits of the map, it is clear that variation of scale can not be avoided. And the larger the scope of the map the greater will be the expansion.

Whenever wind velocity is calculated from the relative closeness of isobars, it follows that formulas for this purpose depend on a considerable number of barometric readings, very few of which can be expected much above the eightieth parallel. A glance at the map will show that if we regard the 20° diameter polar cap as a sort of meteorological limbo where nothing much happens (or if things do happen they will not be observed), and therefore not recorded, it will be seen that we have considerably discounted the drawbacks of two of the six regions where the scale is most violently enlarged. As for the

[1] Presented before the meeting of the American Meteorological Society at New York Dec. 28, 1928.

[2] See Figures 1a and 1b, pp. 130-131.

remaining four points on the Equator where the scale reaches its maximum expansion and conformality fails, these are all in the acknowledged meteorological regions of least action, the doldrums, all well out to sea and in localities, on the whole, free from islands or even the tracks of sea-born trade. If they ever are active meteorologically they are in effect practically passive from want of recording stations either fixed or transient. And here let it be noted that in this rhombic type of map as compared with the conical type the general scale is *not* second-rate at the Equator except at the corners because the very best scale of the map is along the hexagonal mesh forming the perpendiculars to the three sides of each octant with the corners of the hexagons at the centers of the octants. This hexagonal mesh is marked on the map which shows that the three radiating continental plateaux and the Pacific Ocean in their north and south extension share the maximum scale accuracy along with the two Temperate Zones in their extensions east and west.

The seventy-odd great-circle degrees defining a side of this hexagon is in its total extent equal to the same interval along the surface of the globe of derivation. Although scale increase toward the extreme corners is largely mitigated in actual practice for the reasons above stated, it is put forward as a serious objection to the adoption of this map for the purposes of international meteorology in spite of the maps' general superiority in so many other particulars.

The objection is an unreasonble one because, as we have seen, any conformal map of the world *must* develop scale variation and if the same objection had been made to Mercator's chart, where the scale enlargement is infinitely greater, the progress of navigation would have been very seriously delayed.

It seems clear that the mathematically minded meteorologists who worked out the formulas for computing wind velocity from isobar gradients, etc., have considered the problem from an intensive small area, rather than from an extensive large-area viewpoint. Small-scope weather charts such as are used in northwestern Europe would not have to deal with the scale difficulties encountered in surveys of very much greater magnitude. Hence, their formulas would naturally assume the scale factor as a constant.

But now that the scope of meteorology is ever broadening to world wide dimensions, we find the experts, as so often happens, still using the same old formulas derived from past practice, and when confronted with a map literally covering the whole earth they find the assumption of a constant scale will not work. Now if by changing the factors in the formula, so that the scale became a variable, or by dividing the map into regions of progressive scale magnitude these intensive problems could be solved, would this not be wiser than total rejection of a master world map which has so many compensating advantages?

Nothing seems more reasonable than the essential oneness of the world from the meteorologist's viewpoint and several eminent practitioners of this most useful science have told me that a rational world map for their use was a much needed want, a veritable zeitbedurfniss. And this means that the ideal international world map for the study of long-range forecasting problems and the meteorology of the future must have complete trans-equatorial continuity.

I now ask the reader to examine carefully the outlines of this map noting the following items:

(1) Except at six points all parallels and the meridians cross at right angles, an essential of conformality which gives validity to wind roses or compass directions impossible on any map with an oblique graticule. This is extremely important, not only as regards wind direction of both the lower and the upper air, but in the angles formed with isobars and the true direction of isobars and the paths of LOWS or storm tracks and the direction of HIGHS when these are moving.

(2) The meridians are for the most part straight lines or very nearly straight lines.

(3) The parallels are in the main hardly distinguishable from arcs, and as they expand into interlinking ellipses they straighten out into four lines at the Equator so that perfect contact is secured between the north and south octants.

(4) The whole surface of the map like the world itself is a "continuum by replacement" meaning that the overprinted records of moving phenomena can be extended from one octant to another, east, west, north or south continuously.

(5) "Hexagons of strength" (that is, lines of the best scale) bisect the Temperate Zones east and west and the radiating continental plateaux north and south.

(6) The weak parts of the map are in the corners alike of zero human interest and minimum observatorial possibilities.

(7) While the scale increases radially from the center of each octant (where it is slightly subnormal) to its bounds, it is at any point the same in all directions and where at the corners the scale increases the scope diminishes.

(8) The form of the grid is rigidly fixed and unchangeable like Mercator's map no matter what the size or scale. Moreover the computed weave of the graticule in this conformal map lends itself especially to the mathematical side of meteorology in a manner impossible on an equal-area projection. On the other hand, quantitative problems covering, for example, the weight of the atmosphere over given areas, can be easily solved since the actual areas of every 5° by 5° square from the Equator to the pole will be given on each map.

No satisfactory world map is possible which includes both polar integrity and transequatorial continuity, and to this may be added the dictum that no adequate world map can be developed by accident or by the uncontrolled extension of any mathematical weave of coordinates. The creation of a master plan of the world is a matter of design first and foremost, the design of a frame within which intensive mathematical details shall be afterwards subordinated. And this is a task for which the architect is peculiarly fitted owing to his familiarity with form, his mastery of diagram, his training in compromise and his skill in graphic coordination and synthesis.

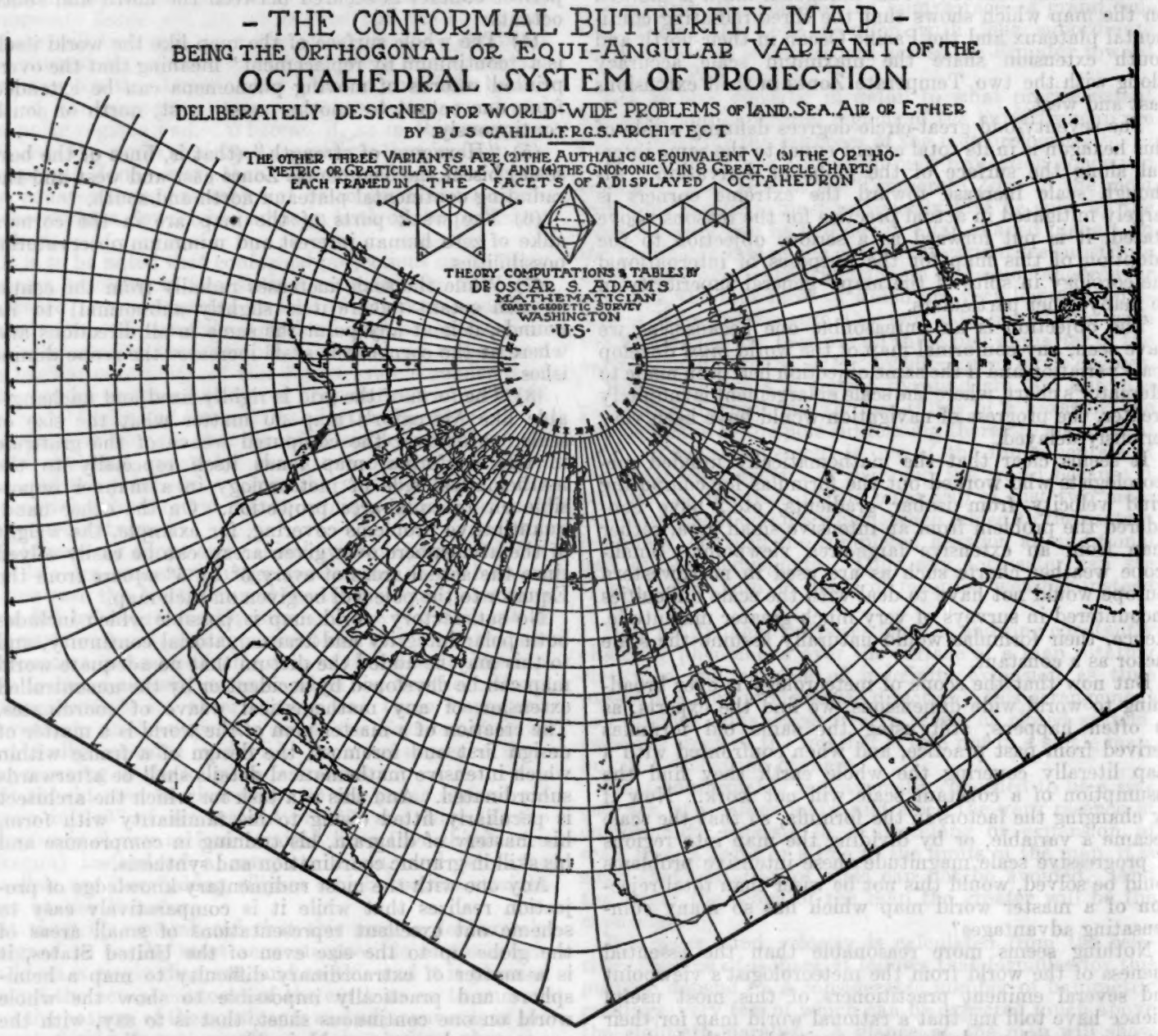
Any one with the most rudimentary knowledge of projection realizes that while it is comparatively easy to scheme out excellent representations of small areas of the globe up to the size even of the United States, it is a matter of extraordinary difficulty to map a hemisphere and practically impossible to show the whole world on one continuous sheet, that is to say, with the same general accuracy obtainable on a small area.

On the conformal butterfly map here shown, however, on account of its deliberately decentralized and articulated design it is possible to show any small country, no matter where, with ordinary atlaslike accuracy. Of large countries the same thing is also true. Suppose, for example, we select the map of the United States printed

A NEW MAP FOR METEOROLOGISTS

EQUALLY SUITABLE FOR SMALL AREAS, CONTINENTS, HEMISPHERES OR THE ENTIRE WORLD

Designed for International Meteorology and Long Range Forecasting


- THE CONFORMAL BUTTERFLY MAP -
BEING THE ORTHOGONAL OR EQUI-ANGULAR VARIANT OF THE
OCTAHEDRAL SYSTEM OF PROJECTION
DELIBERATELY DESIGNED FOR WORLD-WIDE PROBLEMS OF LAND. SEA. AIR OR ETHER
BY B J S CAHILL. F.R.G.S. ARCHITECT
THE OTHER THREE VARIANTS ARE (2) THE AUTHALIC OR EQUIVALENT V. (3) THE ORTHO-METRIC OR GRATICULAR SCALE V AND (4) THE GNOMONIC V IN 8 GREAT-CIRCLE CHARTS EACH FRAMED IN THE FACETS OF A DISPLAYED OCTAHEDRON
THEORY COMPUTATIONS & TABLES BY
DR OSCAR S. ADAMS
MATHEMATICIAN
COAST & GEODETIC SURVEY
WASHINGTON
U·S·

BY SUBSTITUTING RECTANGLES TAKEN BODILY FROM THIS MAP TO COVER THE SMALLER LOCAL AND NATIONAL CHARTS, FOR THE ONES NOW IN USE (WHICH HAVE NO AGREEMENT WITH EACH OTHER) WE GET THE SURPRISING RESULT THAT THESE SEVERAL LOCAL MAPS CAN BE PIECED TOGETHER TO MAKE A MAP OF ANY DIMENSIONS DESIRED INCLUDING THE ENTIRE WORLD. THUS IT WOULD COME ABOUT THAT A DAILY WORLD WEATHER MAP WOULD COME INTO BEING AUTOMATICALLY BY THE MERE SUBSTITUTION AT NO EXTRA COST, OF DAILY SYNOPTIC CHARTS SLIGHTLY DIFFERING FROM THE ONES NOW IN USE.

FIGURE 1a.—The conformal butterfly map for the two hemispheres

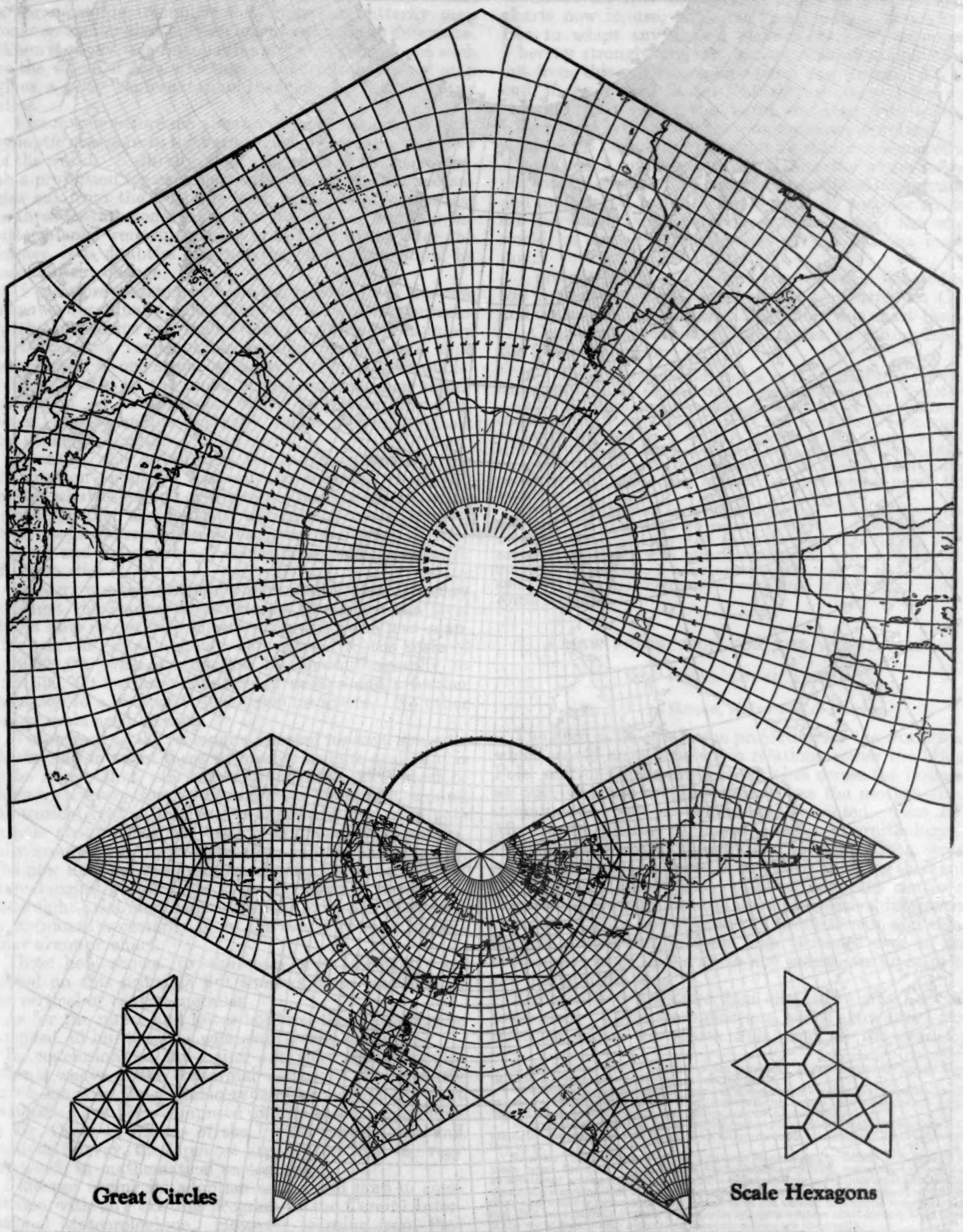


FIGURE 1b.—The conformal butterfly map for the two hemispheres

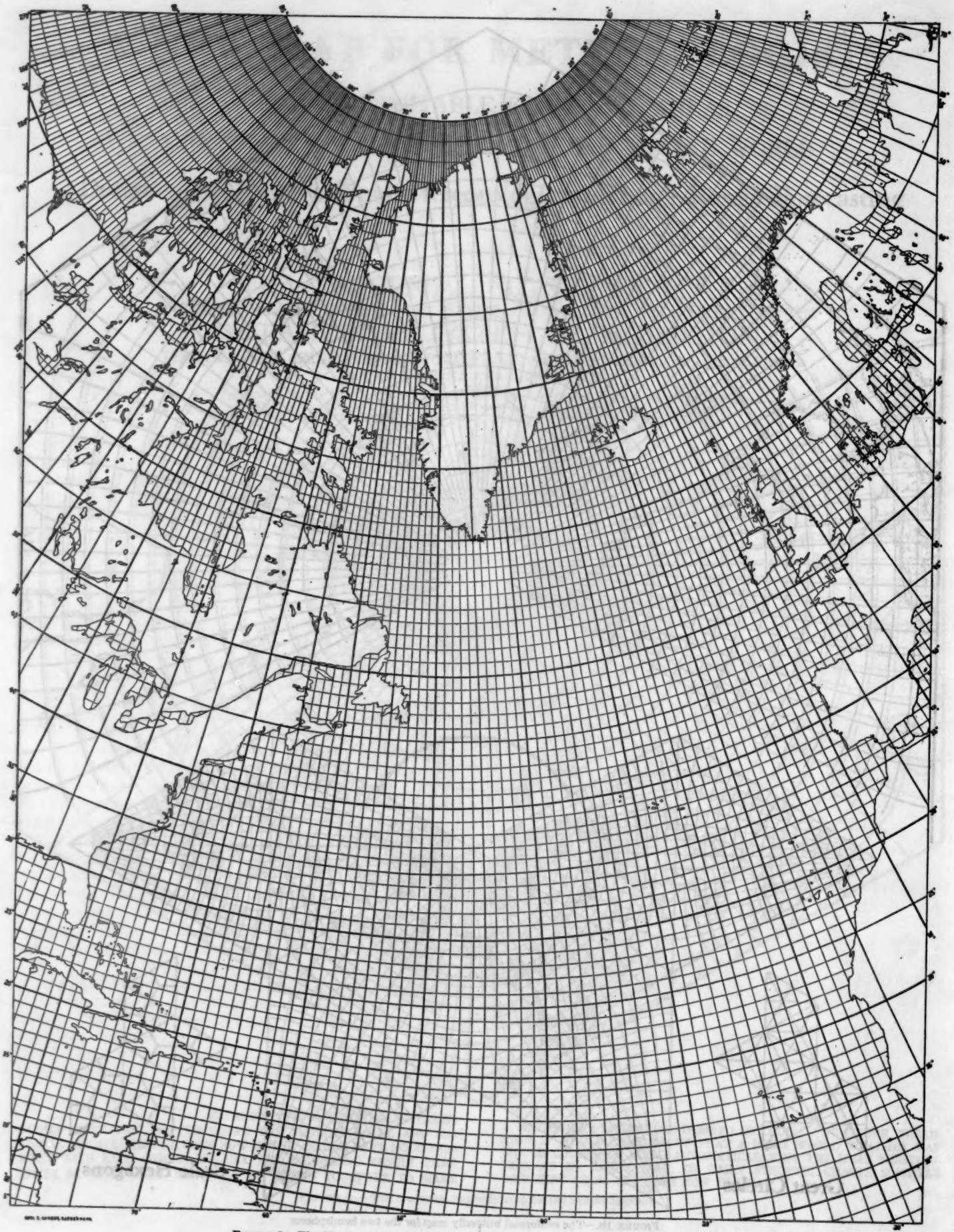


FIGURE 2.—The North Atlantic drawn on the octahedral projection conformal variant

by the Weather Bureau to the scale of 1:20,000,000, a corresponding rectangle cut from the butterfly map looks so similar that only an expert can tell the difference. When it comes to a regional map of very large scope such as the whole of Asia a rectangle cut from this world map gives a *better* representation than can be found in any atlas.

I have now before me about a score of national or local synoptic charts from the various national weather services of the world. Naturally, they are drawn to the most suitable projection for each particular country. Yet rectangles cut from the butterfly map are so nearly identical to these local regional maps that if some fine morning the latter blanks were substituted in any observatory for the former, it is doubtful whether the office force would be aware of the change.

If therefore rectangles of the right scope from the new map were gradually substituted in all weather bureaus (with the reforms and unifications much needed in many particulars), a very notable twofold result would thus be achieved at one stroke with very little cost or trouble.

First, would be the much needed international standardization as to symbols, scale, projection, printing, paper, and technique generally which at present show the utmost diversity.

Secondly, the astonishing result consequent on this substitution—namely, that all the recorded charts no matter what the scope or where the locality would, when pieced together according to the dates, form *a series of world maps for every day in the year,* or oftener as time goes on and the services of the world extend the network of observations.

To carry out this splendid program all that is necessary is to get the leading observatories to replace the local charts now in use with charts taken from the new map. The original cartoon should be executed to the scale of 1:10,000,000 with a reduction by photolithography to 1:20,000,000 for large countries or groups and a further reduction to a scale of 1:40,000,000 for insets. No other size or scale need be used.

With regard to the rectangles selected for local synoptic charts, and to select these with some definite system it is to be noted that, starting with meridian 22½° west of Greenwich every forty-fifth meridian therefrom around the world (eight in number) is a straight line from pole to pole about which the other meridians are symmetrically grouped in curves alternately convex and concave. The new national synoptic charts might well be inclosed in rectangles whose sides were successively parallel to these eight axial meridians. But the axial meridian need by no means necessarily be in the center of each rectangular synoptic chart.

Those here shown to the scale of 1:40,000,000 are slected on this principle but somewhat to one side of the vertical or central meridian.

As for the upper and lower borders, these also can be extended ad lib. to cover whatever area is needed.

In conclusion let me point out that the graticular internal weave of the conformal variant of the butterfly map belongs to the rhombic type of projection and that its details have been computed and its theory expounded by Dr. Oscar S. Adams of the United States Coast and Geodetic Survey, the foremost exponent of this, the very last word, in mathematical cartography.

I am not urging its adoption as a world map in competition with any existing program of the Comité International Meteorologique. However, learning from Professor Van Everdingen and Doctor La Cour that there is no move on foot to reorganize the national synoptic charts now in use, and that "each nation is perfectly free to adopt any map it chooses for local purposes." I hereby strongly urge the substitution of similar charts cut from this map to replace those now in use. To this end, if the United States took the initiative, I feel sure the other nations of the world could be persuaded to follow suit in view of the consequent advantages. It would then be in order to appoint a subcommission of the international committee to reorganize the whole subject of synoptic charts with a view to international cooperation and uniformity, resulting finally in daily weather records for the whole world, each on a single map of the whole world, in accord with the aims of the Pomona resolution.[1]

I present below as Figure 2 the rectangle "cut" from the butterfly map that was selected by Doctor La Cour and drawn in Copenhagen. Regarding this chart Doctor La Cour expressed himself in a letter to the author in the following words:

> My interest in your world map is so far limited that my duty only consists in the construction of weather charts over the North Atlantic and the adjacent coasts. Intentionally I have refused to elaborate charts for other parts of the world, but to meet the wishes of meteorologists and to facilitate for them the construction of supplementary charts, I am inclined to consider it expedient to use for the Atlantic, charts on a scale allowing other people to make use of your butterfly charts for other parts of the world.
>
> Much might be said in favor of the continuation of the projection used for more than 30 years for our file of North Atlantic weather charts. On the other hand the possibility for any one to augment the charts with other butterfly charts is of considerable interest. Wherefore, I have now made a trial in that direction and I send you under separate cover a copy of such chart over the North Atlantic.

A NEW PROJECTION FOR THE WORLD MAP

THE POLAR EQUAL AREA [2]

By J. PAUL GOODE, University of Chicago

The need of an equal area projection for the world map which would show true space relations across the North Pole, and for all the continental lobes across the Equator as well, was the necessity which was the mother of an invention of a new projection here presented. Last July Mr. George Findlay Simmons, curator in ornithology in the Natural History Museum of Cleveland, Ohio, wrote me asking for such a projection. He is studying the hunting falcons. These birds, with an apparent center of dispersal in western Siberia, show progressive differentiation covering the lands about the Arctic Ocean, and along lines of dispersal from these high latitudes over all the continental lobes to the south and across the Equator to the limits of the land.

Reluctantly I answered him that there was no such projection. There are projections which show true space relations across the North Pole; and all the ordinary

---

[1] At the Pomona College meeting of the American Meteorological Society in June, 1928, the following resolution was put and carried:

"Whereas the progress of meteorology and the science of weather forecasting are handicapped by the nonavailability of world-wide weather charts incorporating data for all parts of the globe from which observations are now procurable, and

"Whereas the various national meteorological services publish weather charts on base maps, the scales and projections of which do not conform to any agreed standard, therefore be it

"*Resolved*, That the council of the American Meteorological Society be requested to place before the Chief of the United States Weather Bureau the matter of securing an agreement among the several national weather services to the publication of weather charts of a standard scale and projection, so that those interested in the study of meteorology and weather forecasting may be able to fit the various individual maps together and thus have at their disposal a composite synoptic weather chart for any or all areas of the world from which meteorological observations are obtainable.

[2] A paper read before the Association of American Geographers at the New York meeting Dec. 28, 1928.

projections presenting the earth in the equatorial aspect would serve to show space relations across the Equator, but no one projection would do both. The need, however, suggested the following solution:

The principle used is an old one first enunciated, so far as can be found, by Jean Werner, of Nurenberg, in 1514 A. D.[1] Werner was translating and reviewing the latest "Ptolemy," as general map collections had been called for fifteen hundred years, and remarked that it was unnecessary to use the crude device of Ptolemy for a world map, since the problem of deploying the surface of the globe in an equal area projection could be done in three different ways. The first of these he developed, and it still bears his name. The projection is arbitrary, or conventional; it is strictly equal area; and it proves to be one of the most useful projections we have for geographic maps.

Werner thought only of presenting the earth's surface entire. And when his first idea was developed it provided a map of the earth's surface in a very interesting heart-shaped figure with a sharp sinus down to the North Pole and a sharp point at the South Pole. But though the angles, and therefore shapes, are perfect along the mid meridian, the angles become very acute toward the margin of the map, and therefore shapes are so sadly deformed as to make the projection of no value for map purposes as a world map. But it was very superficial judgment to condemn it on this basis alone. Yet, being condemned, it dropped out of consideration through the centuries.

The psychology involved is interesting. There is a Spanish proverb which expresses it: "Give a dog a bad name and hang him." The English have another saw which illustrates how difficult it is to rise above an evil reputation: "We have the name, we may as well have the game." None of the writers on projections gave it much consideration. Germain found some virtue in it, saying (p. 98), "Cette projection serait donc tout au plus bonne pour les regions voisine du pôle." But as late as 1882 our most distinguished authority on projections, Thomas Craig,[2] gives it a scant inch of space, saying for his last sentence (p. 75), "This projection is not of enough importance to spend any time in obtaining any of the formulas connected with it."

We need not at this time be too severe on Craig or other writers on projections. They have all of them been mathematicians first, and interested in projections mostly as intriguing problems to be solved. This projection is too simple to furnish grist for their mill.

Now a geographer comes to a projection with a different point of view. He is interested in it primarily as a means of providing a map for some definite use. Whether the making of it calls for much mathematics or none is a matter of no consequence to him. And it will be quite pertinent at this point to inquire what are the prime requisites in a projection for use in geography. And the answer is not far to seek.

The most important virtue a projection may have is that it provides an equal area map; that is, a map in which any square inch represents the same number of square miles of the earth's surface as any other square inch in the map. It is a pedagogical crime to enter areal distributions of any sort upon a map like the evil Mercator, which has not the equal area quality.

Next in importance to the equal area quality is that the map provide the best possible shapes to continents and other surface features. And that projection provides best shapes which depart least from the truth of angle and scale. On the globe all meridians cross all parallels of latitude at right angles. The ideal projection departs as little as possible from this right-angle quality. Conic and cylindrical projections provide absolute truth of angle, but may provide monstrosities as maps because of varying scale.

Now to look more intelligently at the projection proposed by Werner, it will be observed that angles and scale, and therefore shapes, are true along the mid meridian from the North Pole to the South Pole. And in high latitudes about the center of projection there is surprisingly little departure from the truth of angle, even in a wide range of longitude. It was the discovery of these fine virtues which led the author in 1910 to choose this projection for his wall map of North America[3] in spite of the evil reputation which had been unjustly saddled upon it from the beginning. The result is a map of North America which has strictly the equal area quality, and which in scale, angle, and shape compares favorably with the best result any projection can give.

So when the demand came for a projection which should deploy all the continental masses so as to keep true space relations across the North Pole, and on each continental lobe across the Equator as well, the virtues of this old discredited projection came to mind, and to it was brought at once the device of interruption of the grill of latitudes and longitudes, which has proved so valuable to the geographer, as applied already to other projections.[4]

This device interrupts the grill so as to give each continent or ocean a mid meridian of its own, thus assuring it of the best possible shape the projection affords. Applied to Werner's device, a wonderful result follows.

For the continents the North Pole is chosen as the center of construction. The three great continental lobes are deployed radially from the North Pole. Each continental lobe is given a mid meridian of its own, part of a radius from the North Pole. On each mid meridian true distances are pointed off for the parallels of latitude. Through these points, with radii from the North Pole, arcs of circles are struck for the parallels of latitude. On these parallels true distances are pointed off from the mid medidian for the positions of the merdians. Through homologous points on the parallels free curves are drawn for the meridians. It follows, since the parallels and the meridians are their true distance apart, that the projection has the equal area quality. It follows also that every point in the map is shown in its true distance from the North Pole.

Since this particular form of this projection is devised to show land distributions, the lands are given the best shapes possible. So an extension of the idea of a mid meridian for the continent is introduced; that is, the mid meridian is allowed to migrate freely on any parallel of latitude to a position which will keep it in the middle of the land at that latiude. This provides surprisingly good shapes for the continents. North America is just about as good as any projection can give singly. South America is good, though "dished" a little on its northern shore because all the parallels of latitude are concave northward. Eurasia, in spite of its 190° spread of longitude,

[1] Germain, A.: Traité des Projections Geographiques. Paris: E. Thunot; 1865?
[2] Craig, Thomas: A Treatise on Projections; quarto, pp. 247. U. S. C. & G. S.; Washington, 1882.
[3] Goode, J. Paul. Wall map of North America; 46 by 66 inches. Chicago; Rand McNally & Co.
[4] (a) Interrupted Sinusoidal Equal Area. Copyrighted, University of Chicago, 1917. (b) Interrupted Homolographic Equal Area. Copyrighted, University of Chicago, 1918. (c) Homolosine, Equal Area, by J. Paul Goode. Copyrighted, University of Chicago, 1923.

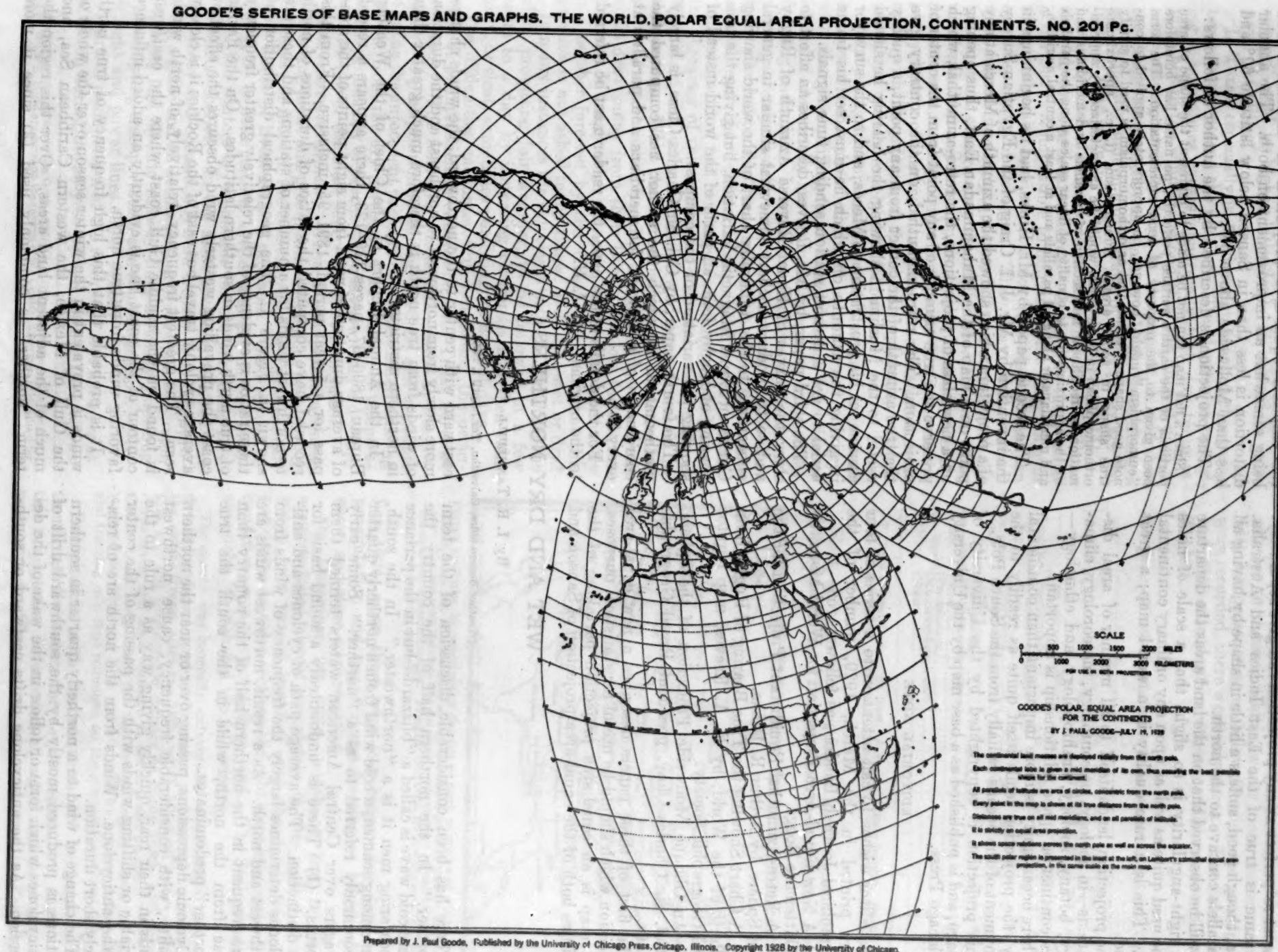

GOODE'S SERIES OF BASE MAPS AND GRAPHS. THE WORLD. POLAR EQUAL AREA PROJECTION, CONTINENTS. NO. 201 Pc.
SCALE
0 500 1000 1500 2000 MILES
0 1000 2000 3000 KILOMETERS
FOR USE IN BOTH PROJECTIONS
GOODE'S POLAR, EQUAL AREA PROJECTION FOR THE CONTINENTS
BY J. PAUL GOODE—JULY 19, 1928
The continental land masses are displayed radially from the north pole.
Each continental table is given a mid meridian of its own, thus assuming the least possible shape for the continent.
All parallels of latitude are arcs of circles, concentric from the north pole.
Every point in the map is shown at its true distance from the north pole.
Distances are true on all mid meridians, and on all parallels of latitude.
It is strictly an equal area projection.
It shows space relations across the north pole as well as across the equator.
The south polar region is presented in the inset at the left, on Lambert's azimuthal equal area projection, in the same scale as the main map.
Prepared by J. Paul Goode, Published by the University of Chicago Press, Chicago, Illinois. Copyright 1928 by the University of Chicago.

FIGURE 1.—The Polar equal-area projection

is almost as perfect as any projection can give separately. The same is true of the East Indies and Australia. Africa, though good, suffers a little in shape by having all its parallels concave to the north.

It will be observed that on the land areas the departure from right-angularity is so slight that a scale of miles can be used quite as well as upon any ordinary continental map. This is a rare quality in a world map; a great virtue.

The projection lends itself to all manner of areal distributions—in geology, paleontology, meteorology, climatology, botany, zoology, anthropology, and ethnology—where continental space relationship is important.

Where ocean unity is more important than continental unity, the projection lends itself quite as readily to the deployment of the oceans radially from the South Pole.

This projection is copyrighted by the University of Chicago, and is published as a base map by the University of Chicago Press.

EDITORIAL NOTE

The editor wishes to call attention to a series of four papers printed in the March, 1929, number of the Geographical Journal, London, as follows:

(1) A New Equal-Area Projection for World Maps, by S. Whittemore Boggs.

(2) A Retro-Azimuthal Equidistant Projection for the World Sphere, by Arthur R. Hinks.

(3) A Chart Showing the True Bearing of Rugby from all Parts of the World, by E. A. Reeves, map curator Royal Geographic Society.

(4) An Oblique Mollweide Projection of the Sphere, by Col. Sir Charles Close, president Royal Geographic Society.

The first of these papers describes a new equal-area projection which should be useful for statistical purposes. The map is an equal-area projection partaking of the qualities both of the equal-area projection of Sanson and the elliptical equal-area projection of Mollweide and being somewhat an improvement on both. The angular distortion is less than in Sanson below latitude 62° and less than Mollweide above 68°.

The projection is described by the author as follows:

> Since a flat map can not be made to represent the shape of large portions of the earth's surface perfectly, no name has heretofore been given to the property of good representation. The term "eumorphism" might, however, be appropriately applied to connote good shape of areas, just as orthomorphism is used to signify true shape in small areas. Eumorphism (i. e., approximate orthomorphism in large areas) would be characterized by approximation to rectilinear intersection of parallels and meridians and by the approximation to equality of linear scales along the parallels and meridians or along all parallels and at least a central meridian.

The second paper, by Mr. Hinks, had its beginnings in the invention by Mr. J. I. Craig of the Egyptian Survey of a projection which showed the azimuth of Mecca at any point on a map of the Muhammadan East, thus opening up a new class of projections, the retro-azimuthal, which preserve the true azimuth of any point from the center of projection. The retro-azimuthal, on the contrary give the true azimuth of the center from any point, a quality useful to the Muslim in showing the bearing he should assume for his prostration to Mecca, and to the surveyor in giving the azimuth on which he must set his frame aerial to get a distant station sending time signals.

The third paper, by Mr. Reeves, describes an effort to show the curves of Equal Reverse Azimuth of Rugby and so to produce a chart somewhat similar in general appearance to the Admiralty chart of the world showing Curves of Equal Magnetic Variation, but giving the true bearing of Rugby from all parts of the world instead of showing the variation of the compass.

The fourth paper, by Col. Sir Charles Close, is largely mathematical in which the author has computed the coordinates of a network for meridians and parallels at every 30°.

For the details of the paper the reader must be referred to the original.—*A. J. H.*

WET AND DRY NORTHERS

By I. R. TANNEHILL

[Weather Bureau office, Galveston, Tex., April 1, 1929]

There has been considerable discussion of the term "norther." In the northern half of the country the severe cold wave is called a "blizzard" but in the parlance of seafaring men it is a "northwester." In the south, even among seamen, a cold wind from a northerly quarter is commonly referred to as a "norther." Some early voyagers over Central American waters termed them "norths." (1) There is undoubtedly a sound basis for this distinction. The average path of cyclones and anticyclones determines largely the frequency of winds from northwest and north. As a result, northwest winds are more frequent in the northern half of the country than those from the north, while in the south the true "norther" predominates.

Cyclonic depressions, passing over or near the northern locality, with considerable frequency, cause northwest winds in their rear, quickly giving way as a rule to the variable or shifting winds with the passing of the center of the anticyclone. Winds from the north are of relatively short duration.

The change of wind to a northerly quarter in southern sections is produced mostly by the southward drift of anticyclones which form or follow in the wake of the depression. As the anticyclone drifts eastward or southeastward with center to the northward, the winds change more slowly from northwest to northeast and the duration of winds from true north is therefore much greater than in northern districts.

In the Annual Report of the Chief of the Weather Bureau, 1896–97, pages 110–123, there appears a record of average duration of wind from eight points of the compass for a 5-year period, 1891–95, inclusive. From this record I have computed the ratios of durations of north to northwest winds for a number of stations and these are shown in Figure 1. The geographical distribution of these ratios is evidence of the relatively greater frequency of true north winds in southern latitudes. On the Pacific coast the prevailing westerly wind obscures the effect of average cyclonic travel but east of the Rockies it is clearly seen. The greatest frequency, relatively, of north winds is found on the middle Gulf coast where the east/west contour of the coast line is evidently an added influence favoring winds from true north.

It is probable that this high frequency of true north winds is prevalent in the winter season over the whole of the Gulf of Mexico, the western Caribbean Sea, and much of the adjacent land areas. Over this region the term "norther" is commonly used (2) since it more

accurately describes the wind than the name "northwester" used in higher latitudes.[1] It is used in some parts of California.

In Texas, especially in the interior, marked changes in temperature attend the norther. The depression preceding it sometimes causes abnormally high day temperatures before the wind shifts and thus the diurnal drop in temperature, normally large in the interior, is added to the change produced by the norther. While these changes are frequently sudden and marked in extent, they are not more so than in many other parts of the country (3).

It is typical of the severe norther moving into Texas that fair weather seems assured. Commonly the weather is fair but it is impossible to determine the percentage of them with rain because it is not possible to make an accurate count of northers. They may include every wind from a northerly quarter, light or strong, and the temperature change may be slight or excessive. The weather in this region is apparently dominated by a high-pressure area, usually, and when the norther is severe the anticyclone is of marked strength. Precipitation is indicated with the advent of the norther, perhaps, but fair weather is usually expected to follow.

From an agricultural standpoint it is quite important to know whether the norther will be wet or dry. If dry, with clear skies, killing frosts form when the wind diminishes and abnormally low temperatures occur in localities favoring radiation. Livestock suffer severely when the wind is accompanied by rain, sleet, or snow. Little shelter is afforded on the Texas coastal plains and thousands of cattle and other livestock have perished in wet northers.

The amount of fuel consumed in heating depends upon the character of the weather as well as the temperature. When cold and wet, the majority of persons remain in their homes. When the norther is dry, outdoor activities, places of entertainment, and public gatherings of various kinds draw many from their homes and less fuel is consumed. In many other ways it is of interest, and rarely is a norther forecast by the Weather Bureau that this question is not asked many times: Will it be wet or dry?

In many instances the sky clears with the arrival of the wind, promising fair weather, to be followed in a few hours to a day by increasing cloudiness and then rain, snow, or sleet, sometimes persisting for several days.

The difficulties encountered in forecasting the occurrence of precipitation in connection with Texas northers are many. The following discussion relates to the frequency of precipitation attending northers and attempts to define the antecedent pressure conditions differentiating the wet from the dry norther. The relation of temperature to probability of precipitation is shown and a description of a few of the more severe northers is included.

Some severe wet northers.—When the temperature is near the freezing point and precipitation continues for a period of 48 hours or more in the coastal region of Texas considerable losses of livestock are probable. Over extensive areas there is little natural shelter and the normal mildness of the winters is responsible for the prevailing lack of artificial shelter. In the most severe type, sleet and snow occur and occasionally rain freezes as it falls, producing a glaze and an accumulation of ice upon telegraph, telephone, and electric railway lines seriously impeding or interrupting transportation and communication. Electric light and power lines suffer equally.

A careful examination of the records of wet northers at Galveston during the 25-year period, 1901 to 1925, shows that such conditions occur infrequently. Limiting the number to those in which two or more consecutive days with temperature at or below freezing and precipitation were recorded, there were only seven. The dates of these and the attendant weather conditions are shown in Table 1.

TABLE 1.—*Weather conditions in seven severe wet northers at Galveston*

Initial date		Feb. 4, 1905	Jan. 6, 1912	Feb. 24, 1914	Jan. 14, 1917	Feb. 4, 1923	Dec. 19, 1924	Dec. 28, 1925
Conditions on first day.	Precipitation	0.18	0.12	0.37	T.	2.15	0.68	0.01
	Minimum temperature	29	30	27	32	31		26
	Other	I.	St. S.	St. S.	S.		30	St. S.
On second day.	Precipitation	T.	.28	.03	T.	.01	.12	.09
	Minimum temperature	32	29	28	32	29	28	27
	Other			S.		St. I.	St.	I.
On third day.	Precipitation						.06	
	Minimum temperature						28	
	Other						St. I.	
On fourth day.	Precipitation						.08	
	Minimum temperature						32	
	Other							

T. Trace of precipitation. St. Sleet. S. Snow. I. Rain freezing. Precipitation in inches and hundredths. Minimum temperature Farenheit.

Sleet, snow, or rain freezing as it fell accompanied six of these northers. The most severe was that of December, 1924, when there were four consecutive days with precipitation and temperatures freezing or below; sleet, snow, and glaze were recorded.

FIGURE 1.—Ratios, in percentage, of duration of north to northwest winds, average annual, years 1891–1895, inclusive, at a representative group of stations; that is, the entry 87 at Memphis indicates that the north winds averaged annually 87 per cent of the northwest winds in duration. Along the Gulf coast, north winds are more frequent than winds from the northwest

On December 20, 1924, telephone and telegraph services failed almost completely in this section, interurban cars ceased running, and thousands of cattle perished. In some sections the cold combined with other conditions was the worst since 1895. The State weather summary (4) included the following:

> The month was generally unfavorable to agricultural interests, due to insufficient moisture, in western and central Texas and to the severe freezes after the 18th, which killed all tender vegetation and did considerable damage to hardy truck, oats, young citrus trees, and lesser damage to citrus fruits on trees. * * * Cattle losses were heavy in the coastal section where the cold wave of the 18th and 19th was attended by a heavy fall of sleet and freezing rain that remained on the ground for several days.

Precipitation with temperatures 40° or below continued at Galveston for seven consecutive days. In this respect also it exceeded all other records in the 25-year period. The nearest approach was in February,

[1] A description of northers in the Gulfs of Mexico and Tehuantepec and in the Canal Zone by Willis E. Hurd appeared on the reverse of the Central American Pilot Chart for February, 1927.

1905, when there were six consecutive days with precipitation and minimum temperatures 40° or lower.

The records of five wet northers in which the temperature was 40° or lower with precipitation on four or more consecutive days is shown in Table 2.

TABLE 2.—*Minimum temperature and precipitation daily in wet northers with four or more consecutive days 40° or below and precipitation*

Initial date		Jan. 26, 1902	Feb. 3, 1905	Jan. 13, 1917	Dec. 19, 1924	Dec. 28, 1925
First day	Minimum temperature	36	34	35	30	26
	Precipitation	.02	.09	.02	.68	.01
Second day	Minimum temperature	32	29	32	28	27
	Precipitation	.13	.18	T.	.12	.09
Third day	Minimum temperature	33	32	32	28	33
	Precipitation	.09	T.	T.	.06	.90
Fourth day	Minimum temperature	37	34	37	32	39
	Precipitation	.30	T.	T.	.08	T.
Fifth day	Minimum temperature	39	36	37	40	------
	Precipitation	.12	.21	.01	T.	------
Sixth day	Minimum temperature	------	35	------	34	------
	Precipitation	------	.74	------	.27	------
Seventh day	Minimum temperature	------	------	------	30	------
	Precipitation	------	------	------	T.	------

T. Trace of precipitation—less than 0.01 inch.

Dry northers.—In the majority of cases rain accompanies or immediately precedes the arrival of the norther. Occasionally rain continues into the first day of freezing temperature when the norther is severe but it generally ceases with the fall in temperature and before the freezing point is reached. The latter class may be included with the dry northers. In the 25 years of record discussed, there have been four northers, in which the freezing temperature was reached, without precipitation either during the period of low temperature or for several days prior to its arrival. The record in this respect was in 1912. On February 4 of that year the temperature fell to 27° and there was no precipitation and there had been none since the 28th of January and none occurred until the 8th of February. Three other northers in this period, with minimum temperatures below freezing, were not accompanied by precipitation, and in these instances none had occurred during the three days preceding.

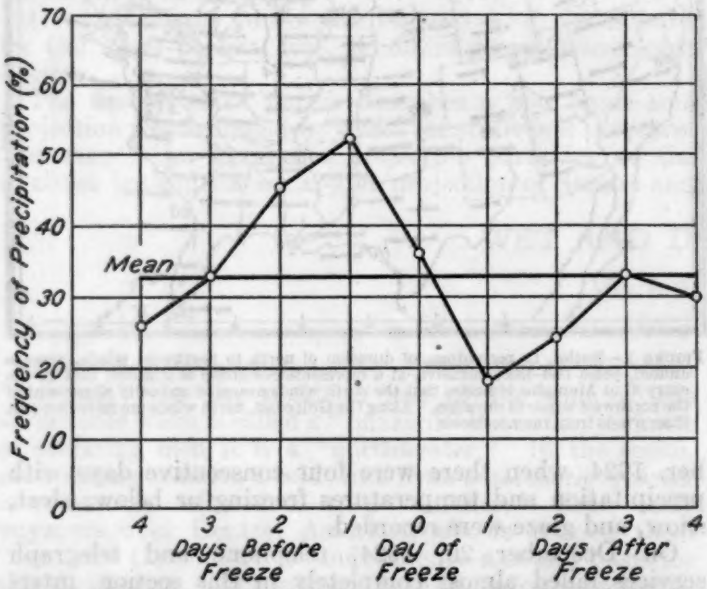


FIGURE 2.—Probability of precipitation, per cent, on days with a freeze, the four days prior to the freeze and the four days following the freeze. From 102 occurrences at Galveston, Tex., 1901 to 1925

There have been 12 northers with two or more consecutive days of freezing temperature unaccompanied by precipitation and these are listed in Table 3. Dates, minimum temperatures and occurrence of precipitation for these northers are shown there.

TABLE 3.—*Dry northers, with freezing temperature, in period 1901–1925 at Galveston, Tex.*

Initial date of freezing without rain	Minimum temperature on first day, second day, and third day (without precipitation)			Initial date of freezing without rain	Minimum temperature on first day, second day, and third day (without precipitation)		
Jan. 14, 1905 [1]	30	29	------	Dec. 8, 1917 [2]	30	31	------
Feb. 13, 1905 [1]	17	22	------	Dec. 20, 1917 [3]	31	26	------
Feb. 15, 1909 [1]	24	29	------	Dec. 21, 1916 [3]	32	26	------
Jan. 3, 1919 [1]	29	28	------	Jan. 5, 1924 [1]	32	26	32
Dec. 14, 1914 [1]	28	32	------	Dec. 22, 1925 [3]	31	32	------
Jan. 2, 1911 [2]	24	19	23	Feb. 4, 1912 [4]	27	28	------

[1] Preceded by 1 day with freezing temperature and precipitation.
[2] Rain on day preceding first with freezing temperature.
[3] No rain on 3 days immediately preceding first with freezing temperature.
[4] No rain on 6 days preceding occurrence of a minimum temperature at or below freezing.

Frequency of precipitation preceding and following freezes.—During the years 1901 to 1925 there were 102 days on which the minimum temperature, as an integer, was 32° or below.[1] For each of these 102 occurrences, the precipitation records were examined for the four days preceding and the four days following the freeze as well as the day of the freeze. The total number of occurrences of precipitation for each day of the period, beginning with the fourth day before and ending with the fourth day following the freeze, were as follows: 27, 33, 46, 53, 37, 18, 24, 34, and 31. Graphically the percentage probability of precipitation is shown in Figure 2.

Amounts of precipitation of 0.01 inch or more, as here tabulated, were most frequent on the day preceding the freeze, and least on the day following. The effect of average cyclonic travel is evident. A slight secondary maximum of frequency is indicated on the third day following the freeze. The interval between these maxima approximates the average interval of time between cyclones.

In winter, the average frequency of precipitation, 0.01 inch or more in 24 hours, is 28 per cent. For the 9-day period of Figure 2, it averages 33 per cent. The greater frequency in these periods is probably due to more energetic cyclonic activity during intervals when freezing temperatures have occurred.

Probability of rain as related to the temperature.—Theoretically the probability of a certain amount of rain should diminish as the temperature falls because of the lowered capacity of the atmosphere for moisture. There are, however, other forces influencing the frequency of rain, some of which vary in harmony with the temperature, obscuring the relationship. One of these, cyclonic activity in lower latitudes, is greater when temperatures are low because the action of the cyclone in drawing air from higher latitudes is one of the factors in the production of low temperatures. Greater temperature contrasts are associated with and probably induce more intense cyclones.

The 2,256 temperatures at 7 a. m. in winter, 1901 to 1925, inclusive, have been distributed as shown at "A" in Figure 3. The records were examined for this period to determine the relationship between temperature and

[1] Following the usual rule for decimals, a temperature of 32.5° is an occurrence of 32° in whole numbers, but the tabulation of occurrences of 32° or below in the Weather Bureau does not include readings of 32.1° to 32.5°, hence there were only 89 occurrences. In this paper, readings from 32.1° to 32.5° have been included because of the larger number of cases afforded the study. Due to slight local variations of the temperature there may be a freeze in the immediate vicinity when the station thermometer reads slightly above 32°.

precipitation occurring in the 12-hour period from 7 p. m. of the same day to 7 a. m. of the following day. The total number of occurrences following each 7 a. m. temperature, to even numbers, is shown in Figure 3 at "B". The frequencies vary with the temperature being greatest at 62°. However, the probability of precipitation is not thereby indicated since there is greater opportunity for gain following the more frequent temperatures.

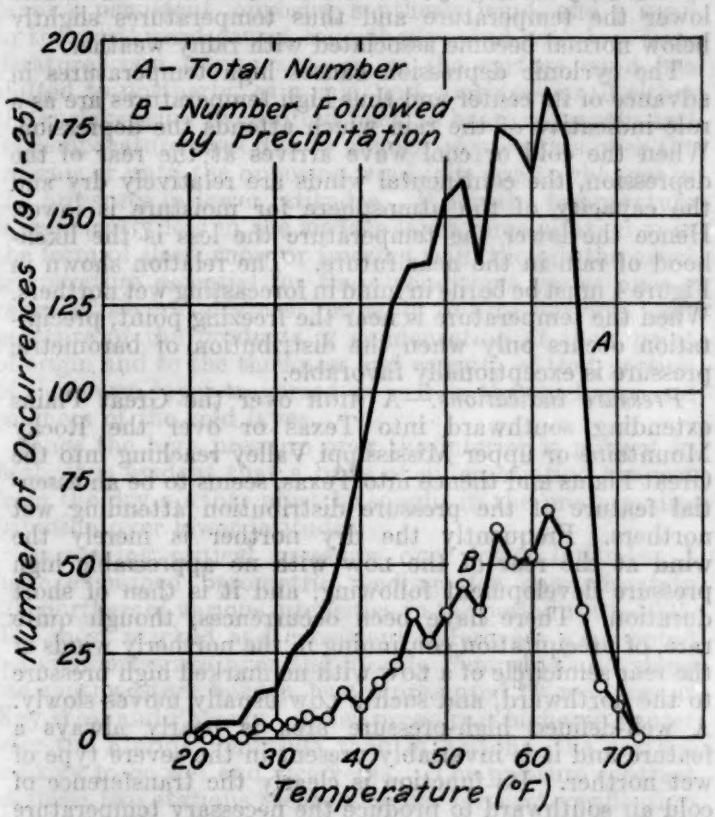


FIGURE 3.—Total number of occurrences of each temperature (to even numbers) at 7 a. m. at Galveston, 1901 to 1925, shown at "A." The total number of such even [1] temperatures, followed in the 12-hour period next thereafter; that is from 7 p. m. of that date to 7 a. m. of the next following date, by precipitation, including traces, shown at "B." Winter temperatures only

To determine the probability that rain will follow the occurrence of a certain temperature, it is necessary to find the ratio between the whole number of such temperatures and the number followed by precipitation. This being done, the probabilities, in percentages, are averaged for groups, with five even readings in each group and the results are shown in Figure 4. The probability increases with the temperature. In the upper curve, all amounts, including traces and 0.01's, are included; in the lower curve amounts less than 0.02 inch are excluded. It will be seen that at temperatures 22° to 30°, the average intensity of precipitation in the following period, 7 p. m. to 7 a. m., seems to be low, there being only 4 per cent probability that amounts greater than 0.01 inch will occur.

At temperatures below 32° there is small likelihood that precipitation will occur in quantities sufficient to make a forecast of fair weather unsuccessful.[2] It has been shown that precipitation occurred on 36 per cent of days with minimum temperature at or below 32° but there have been only seven instances from a 25-year record of precipitation extending into the second day of freezing, the high frequency on the first day being due to rain falling in the same 24-hour period but before the temperature had fallen to the freezing point.

After the temperature has reached 32° it is quite rare that precipitation is recorded. Of course the temperature does not remain continuously at 32° thereafter; on the average day with a minimum at or below 32° considerably higher temperatures are sometimes recorded and readings somewhat higher always occur. The amounts that do fall after 32° is reached are usually small and in the form of sleet, light snow, or a mist or fine drizzle of rain.

The intensity of precipitation is greatest in the warm months and least in cold months (5). The intensity of rainfall, though with numerous exceptions, varies with the temperature of the dew point. In a discussion of the distribution of excessive precipitation, Henry (6) remarked:

> The higher the temperature of the air, the greater its capacity for water vapor, whence it follows that the precipitation must be more frequent and in larger amount in those regions having the higher dew point.

Conversely, a greater time is required for a given amount of rain to fall in cold periods than in warm, and hence the period of attendant cloudiness is extended, and with it the period over which daytime temperatures are lowered by the cloudiness and precipitation and directly or indirectly the night time temperatures. Wet periods are therefore associated with average temperatures below the normal and dry seasons with relatively high temperatures.

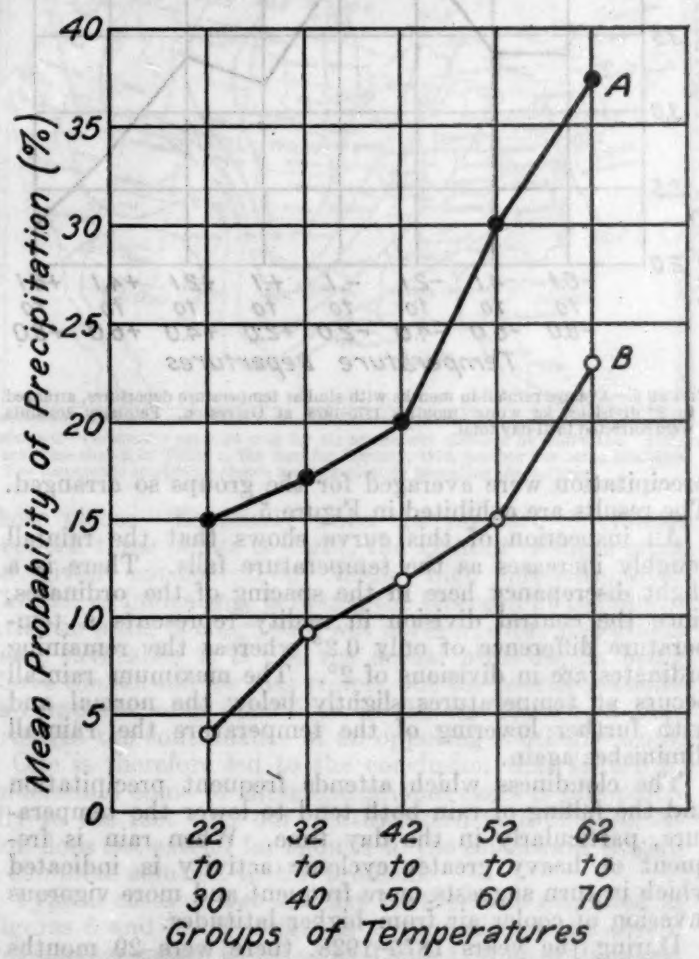


FIGURE 4.—Probability of rain as related to the temperature. A, probability in per cent that precipitation, traces and 0.01's included, will follow a 7 a. m. temperature in the group indicated, in winter, prepared from records at Galveston, 1901–1925. B, probability of precipitation, including only amounts greater than 0.01 inch.

[1] All temperatures are included but the record is in degrees and tenths, and the nearest even temperature is used, whole numbers, following the rule that when the temperature is exactly odd, the next lower number is used; that is, 31 becomes 30.

[2] A forecast of rain, by Weather Bureau rules, is verified on the occurrence of precipitation in any amount, but a fair weather forecast is defeated only when precipitation exceeds 0.01 inch.

Is warm weather dry and cold weather wet?—It has been shown that the probability of rain is greater when the temperature is high than when it is low. To reconcile this conclusion with the fact that temperature departures are generally negative in wet periods, the records from 1875 to 1928, inclusive, of mean monthly temperatures were grouped according to the magnitude of departures from the normal. The values for months prior to 1875 were not used, since the means for some of those months were determined from the means of the 7 a. m., 2 p. m., and 9 p. m. observations, whereas the calcu ations thereafter were from the maxima and minima. The normals used were those adopted in 1922 and the departures from old normals as entered in the records were disregarded. Records of winter months were used and months grouped according to departures of mean temperature from normal as follows: From 0.1 to 2 above normal, from 2.1 to 4 above normal; from 0.1 to 2 below normal, etc. Total monthly catches of

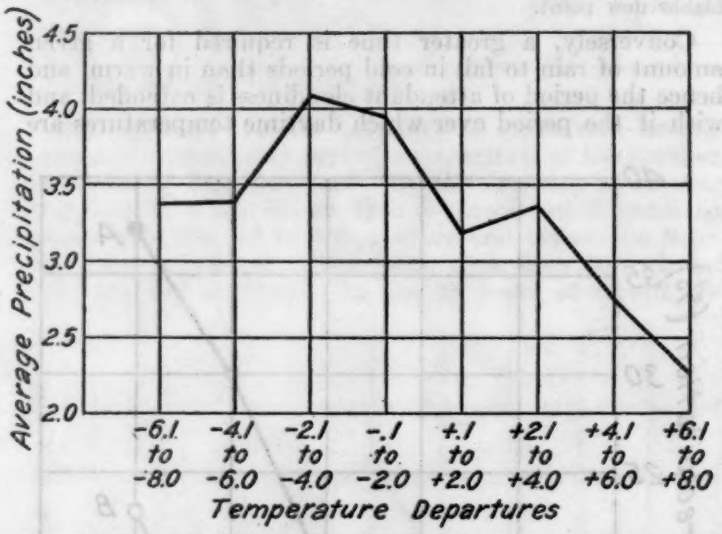


FIGURE 5.—Average rainfall in months with similar temperature departures, arranged in 2° divisions, for winter months, 1875–1928, at Galveston. February amounts were corrected to 31-day total.

precipitation were averaged for the groups so arranged. The results are exhibited in Figure 5.

An inspection of this curve shows that the rainfall roughly increases as the temperature falls. There is a slight discrepancy here in the spacing of the ordinates, since the central division in reality represents a temperature difference of only 0.2° whereas the remaining ordinates are in divisions of 2°. The maximum rainfall occurs at temperatures slightly below the normal and with further lowering of the temperature the rainfall diminishes again.

The cloudiness which attends frequent precipitation and the falling of rain both tend to lower the temperature, particularly in the day time. When rain is frequent or heavy greater cyclonic activity is indicated which in turn suggests more frequent and more vigorous invasion of cooler air from higher latitudes.

During the years 1875–1928, there were 29 months with temperature 32° or below on three or more days and during these months the rainfall averaged 3.36 inches. The normal monthly fall for that period is 3.33 inches. There were 22 months during which the temperature fell below 25° and during those months the rainfall averaged 3.22 inches or only slightly below the normal of 3.33 inches.

The occurrence of one or more cold waves during the month seems to have no material effect upon the rainfall. The probability of rain in the immediate future seems to be less when temperatures are low but this effect is probably counterblanced by the increased ra nfall due to cyclonic activity preceding the cold wave. As shown by monthly averages, rainfall and attendant cloudiness lower the temperature and thus temperatures slightly below normal become associated with rainy weather.

The cyclonic depression causes high temperatures in advance of its center and thus high temperatures are as a rule indicative of the rain which attends the depression. When the cold or cool wave arrives at the rear of the depression, the continental winds are relatively dry and the capacity of the atmosphere for moisture is lower. Hence the lower the temperature the less is the likelihood of rain in the near future. The relation shown in Figure 4 must be borne in mind in forecasting wet northers. When the temperature is near the freezing point, precipitation occurs only when the distribution of barometric pressure is exceptionally favorable.

Pressure indications.—A HIGH over the Great Plains extending southward into Texas or over the Rocky Mountains or upper Mississippi Valley reaching into the Great Plains and thence into Texas, seems to be an essential feature of the pressure distribution attending wet northers. Frequently the dry norther is merely the wind at the rear of the LOW with no appreciable high pressure development following, and it is then of short duration. There have been occurrences, though quite rare, of precipitation continuing in the northerly winds of the rear semicircle of a LOW with no marked high pressure to the northward, and such a LOW usually moves slowly. A well-defined high-pressure area is nearly always a feature and it is invariably present in the severe type of wet norther. Its function is clearly the transference of cold air southward to produce the necessary temperature contrasts for continued precipitation.

It is generally conceded that precipitation under these circumstances is caused by the overriding of a moist southerly wind above the cold surface norther. Though observations of the upper air bearing on this question are limited in number there is considerable evidence supporting this conclusion.

Brooks (7), presented a diagram representing conditions responsible for the formation of various types of snow, sleet, glaze, etc., with a relatively warm southerly wind flowing over the chilly northerly winds. He noted also a convective layer, where conditions are favorable for precipitation.

Meisinger (8), after an exhaustive examination of conditions attending the widespread sleet and glaze storm of January, 1920, concluded that,

> * * * One of the major premises of a sleet forecast is the presence in the southeast of a "high," the temperatures within which are not so low as usual, just off the coast of southeastern United States. Such a condition persisted until the last few hours of the period. (January 20–26, 1920.) Moreover, the belt of high pressure, evidently centered far north in Canada, gave an abundant supply of cold air, sweeping down from the deep snow fields of the north far into the United States toward the general area of low pressure along the southern coast. The return flow of warm, moist air, riding over the wedgelike encroaching north wind, was cooled and forced to precipitate rain, sleet, or snow, over most of the eastern United States throughout the period.

These conclusions were in agreement with those of Frankenfield (9), who earlier stated the conditions that were favorable for sleet and ice storms, one of them being the presence of moderately high pressures and high temperatures over the East Gulf and South Atlantic States.

Since sleet or glaze accompanied five of the seven wet northers listed in Table 1, it may be assumed that a warm

overflow is present in the wet norther of Texas, and that the only difference between the storm that produces sleet and glaze and the other that causes only a cold rain is in the temperature of the surface layer and of the southerly wind, overriding it. When pressures in lower latitudes favor a persistent, opposing southerly wind, and a HIGH to the northward causes a northerly wind with low temperature, rain begins as soon as the surface wind has shifted to northerly, as a rule, and continues until either the surface wind has shifted back to southerly again and its temperature rises due to change of pressures over the interior or until the opposing wind fails due to changes in the pressures in lower latitudes. When the temperature is sufficiently low in the surface layer, precipitation is in the form of sleet, snow or freezing rain, though the exact temperature essential for these conditions varies over a range of several degrees, probably due to varying temperature of the products of condensation at their point of origin and to the thickness and warmth of that portion of the warm layer traversed as well as the thickness and coldness of the cold layer.

Since the high pressure over the interior is present in both, it is evident that a basis of differentiating the wet from the dry norther must be sought in the pressure distribution over lower latitudes.

In seeking critical pressures over lower latitudes, I have examined barometric readings for approximately 200 northers of various intensities, in the period 1901–1925. The most marked and consistent differences were noted between pressures over the Florida Peninsula and along the southwestern border, best represented by readings at Key West and Phoenix. When pressure is higher in winter over the Florida Peninsula than in Arizona, the norther is likely to be wet and vice versa. The pressure contrast at these two stations yields a higher forecast verification than any other. As a test I have taken at random the first 100 maps, showing a winter HIGH over the Great Plains and cold northerly winds reaching the Texas coast or giving promise of doing so shortly. The forecast was verified on the occurrence of precipitation during the 24-hour period from 7 p. m. of the same day to 7 p. m. of the following day. Cases in which the pressures at Key West and Phoenix were identical were disregarded. Including all cases, with difference of 0.02 inch or more, the verification was 72 per cent correct. Including instances in which the difference was 0.10 inch or more, 61 in all, the verification was 84 per cent. Including only those cases in which the difference was 0.20 inch or more, verification was 93 per cent, there being one failure in 14 forecasts.

Considering the fact that the barometric readings at only two stations are used, this is a remarkably high verification. Of course the distribution of pressure is limited to those cases in which a "high" appears over or near the Great Plains causing northerly winds over Texas, or giving every promise of doing so. The conditions necessary for the arrival of the norther on the Texas coast have been discussed by the writer in a previous paper (**10**).

During the sleet and glaze storm studied by Meisinger and previously referred to, January 20–26, 1920, a typical wet norther prevailed at Galveston. Temperatures, however, were not low enough for sleet or glaze. At Galveston precipitation began shortly before the wind shifted to northerly, pressure being considerably lower at Phoenix than at Key West, and having been so during the preceding 24 hours. Northerly winds with intermittent rain continued at Galveston and the pressure at Phoenix was lower than Key West until some time between the p. m. observation of the 23d and the a. m. observation of the 24th, when it became higher at Phoenix. Rain ceased at Galveston about 1 a. m. January 25.

A study of the exceptions to this rule leads to the conclusion that what is needed is the pressure at a point about the longitude of Phoenix and the latitude of Key West.

In the absence of such a datum, there are other conditions, apparently indicative of rain, though not consistently so. One of these is high pressure over the States of Nevada, Washington, and Oregon. Low pressure centered near Seattle is decidedly unfavorable for the development of a wet norther in Texas, as is low pressure in the Lower Mississippi Valley. A LOW in the west Gulf is apparently blocked by the HIGH to the northward when pressures at Vicksburg and New Orleans are higher than at Galveston and Corpus Christi and rain is indicated in the immediate future, this being true only when the HIGH has advanced well into the plains and northerly winds extend over Texas.

The most valuable index, aside from the pressures at Key West and Phoenix, is the barometric tendency at

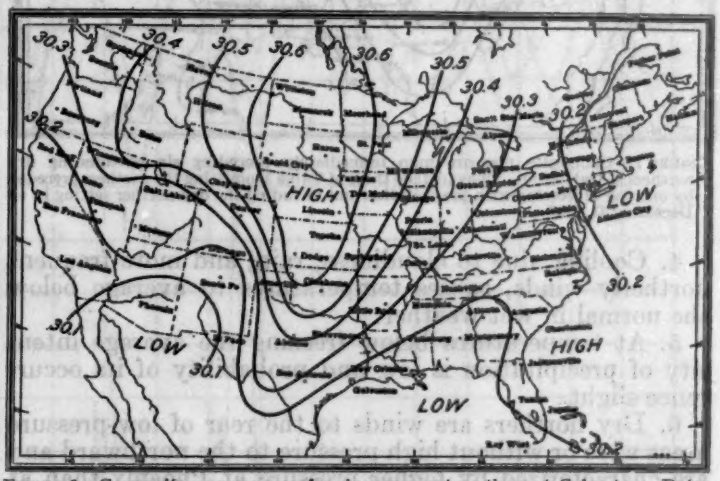


FIGURE 6.—Composite pressure map for six severe wet northers at Galveston. Dates are those shown in Table 1, the map for January, 1912, norther not being available. The barometric conditions shown are immediately preceding the norther

those places. Especially when the pressure differences between these points is slight, the 12-hour changes must be given consideration. While high pressure over Florida, as indicating, perhaps, the strength of the South Atlantic HIGH, is a sign of a wet norther, other conditions being favorable, it is not the actual pressure, as being above the normal for that region, but the *relative* pressure as compared with conditions in the far Southwest that presages the continuance of an opposing southerly wind.

One is therefore led to the conclusion that failure to understand some of these exceptional cases is due partially to the fact that our Southwestern field of observation does not extend far enough to the southward to give a complete solution to the problem.

Typical cases of wet and dry northers are exhibited in Figures 6 and 7. The first is a composite of the severe wet norther maps, as listed in Table 1, that of January, 1912, missing. The second is a composite of the five maps for dates shown in Table 3, in which two or more days with freezing temperature occurred without precipitation and were not preceded by a day with precipitation and freezing temperature. The dry norther of December 31, 1927, being of this class, was also included to make the number equal to that of the wet northers.

CONCLUSIONS

1. Severe wet northers, with two or more consecutive days with freezing temperature and precipitation, occur in the vicinity of Galveston about once in three or four years.

2. The probability of rain is least on the day following the freeze and greatest on the day preceding.

3. The higher the temperature in winter the greater is the probability of precipitation, based on occurrences during the following night period.

FIGURE 7.—Composite pressure map immediately preceding six outstanding dry northers at Galveston. They include those of Table 3, omitting the northers preceded by one day of freezing with precipitation and including the dry norther setting in on December 31, 1927

4. Cooling, due to cloudiness, rain, and more frequent northerly winds, causes temperatures to average below the normal in wet weather.

5. At temperatures below freezing the average intensity of precipitation is low and probability of its occurrence slight.

6. Dry northers are winds to the rear of low-pressure areas with or without high pressure to the northward and are characterized by higher pressure at Phoenix than at Key West when the HIGH is the dominant factor.

7. Wet northers are winds from high-pressure areas over the Great Plains or adjoining sections, overridden by warm, moist, southerly winds. They are characterized by higher pressure at Key West than at Phoenix.

8. Other conditions favoring the wet norther are high pressure extending westward through Nevada, Oregon, and Washington, pressure tendency downward at Phoenix and upward at Key West, and relatively high pressure in the Lower Mississippi Valley.

9. Other indications of the dry norther are the reverse conditions—low pressure centered near Seattle or thereabouts, pressure tendency downward at Key West and upward at Phoenix and a well-defined depression in the Lower Mississippi Valley.

10. Southwestern reports should extend to approximately the latitude of Key West.

ACKNOWLEDGMENT

Dr. Charles F. Brooks read the manuscript of this paper and offered a number of suggestions which were followed in making revisions. The writer gratefully acknowledges Doctor Brooks's assistance and encouragement.

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A CRITICAL TEST OF THE PLANETARY HYPOTHESIS OF SUN SPOTS

By DINSMORE ALTER

[University of Kansas, Lawrence, Kans., February 23, 1929]

With Schwabe's discovery that there is a cycle in sun-spot numbers, nearly equal to the period of the planet Jupiter, it is obvious that a study of the possibility of the tides produced by the planet Jupiter, on the sun, as a cause of the phenomenon would follow. The first paper on such a hypothesis seems to be that by Fritz in 1866 (1). This was followed by a series of papers on the same and related subjects by him and by Wolf, throughout the remainder of the century. It is a great pity that this most important of all series of sun-spot studies is not more generally available. Fortunately synopses and résumés are common. The MONTHLY WEATHER REVIEW has recently published a translation by Mr. Reed of one of Fritz's more important papers, a proceeding in which the editor is to be commended and urged to continue (2).

However, the most important single analytical study of the possibilities of the hypothesis was that by E. W. Brown (3). In this paper Professor Brown compares the observed epochs of maxima and minima of all available data with the curve formed by a rough combination of the tides of Jupiter and Saturn. The agreement is so excellent that usually it would be accepted as sufficient evidence of the truth of an hypothesis. In this case, however, the fact that the tidal forces are negligible in comparison with the sun's own gravitational field made even such strong evidence seem insufficient and the hypothesis found very few followers. Many other hypotheses have been advanced but uniformly have met with unsurmountable objections. For a number of years the feeling has been growing that the variations can not be accounted for by any fairly constant periodicities and that investigations were a waste of time.

Recently the writer made another analysis (4) of the sun-spot numbers, applying the new correlation periodogram. This periodogram, which compares the actual shape of two sections of the curve, and not merely one Fourier term at a time, is more sensitive than other methods in determining, and weighing the probability of actual physical existence of irregularly shaped repetitions of data. In that paper the conclusion was reached that if a series of periodicities do exist which account for the main variations in sun-spot numbers they must be harmonics of approximately 252 years.[1]

About this time a conversation with Professor Brown led to the computation of an ephemeris based on Brown's early paper. The ephemeris fitted the data during the 30 years since the paper had appeared as accurately as during the years used in the original paper. It is given here as Figure 1. Such a fulfillment of predictions was unique in the history of the subject.

Following this, the writer examined the 252-year period to find whether it bore any relationship to the planetary tidal periods. It was found that 250 years, well within the limits of error of his work, was an almost-perfect least common multiple of the tidal periods of all the planets from Jupiter outward.

During the past few years modern physical theory and the spectroscopic study of the solar atmosphere have removed the great objection which has existed with respect to the tida hypothesis, by showing that the reversing layer is in almost perfect equilibrium between the inward force of gravity and the outward force of light pressure. Under such a condition, long thought to exist only when the rate of rotation was rapid enough, very small tidal forces might conceivably produce very marked disturbances. If so, they would be a common feature for all stars surrounded by planets.

In all this work the tides of the inner planets, equal in force to those of the outer, were neglected. Sun spots develop slowly and often last for many months. A period of two or three months could not be expected to show a variation comparable with that which would be produced by an equal force acting through a longer

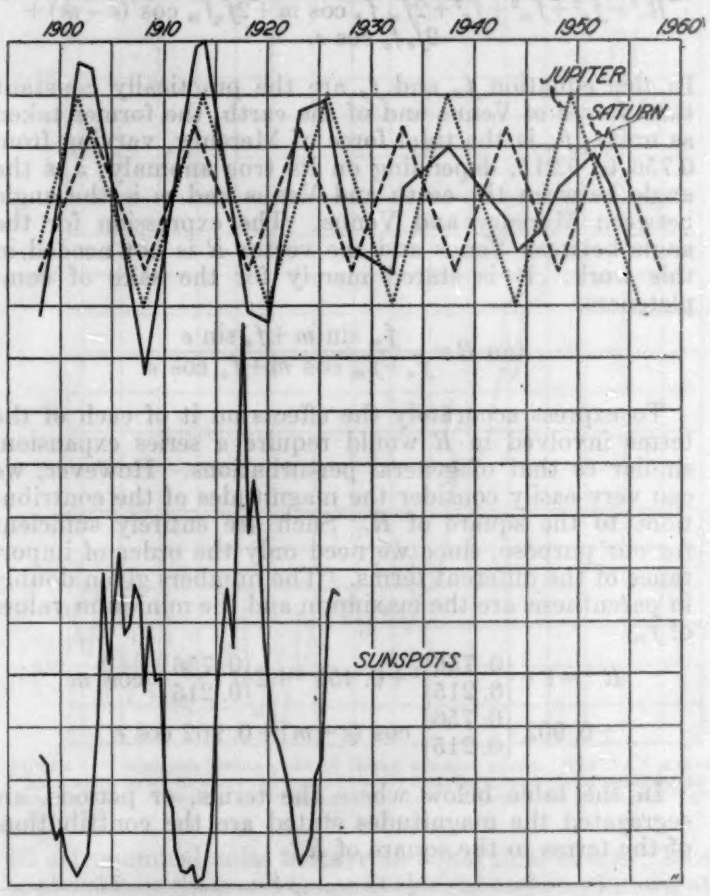

FIGURE 1.—A continuance of Prof. E. W. Brown's curves as published in Monthly Notices of Royal Astronomical Society, volume 60, 1899-1900. The dashed line marked "Jupiter" represents the tidal force due to the eccentricity of that planet and the dashed line marked "Saturn" is the expression of the tidal force due to Saturn's position in the sky with respect to Jupiter and the full curve is their sum. The minima are at the top, the maxima at the bottom

period. However, there should be some such variation present, its magnitude being a function of the force and of the length of period through which it acted. An examination of the data for such periods might form a critical test of the hypothesis.

The calculation of the periods and magnitudes of such tidal forces is standard and need not be repeated here. The periods are the synodic periods of the three planets and in addition the period of revolution of Mercury, due to its large eccentricity. The eccentricity of Mercury will also cause a variable amplitude to its combinations with Venus and the earth. The period due to the combination of Venus and the earth may be considered as a

[1] Cf. Alter Dinsmore, A new analysis of sun-spot numbers; Mo. Wea. Rev. *56*:401.

constant one. *We can calculate in advance exactly where such periodicities should show peaks in the periodogram. If they are found there regularly, the truth of the hypothesis is established. If they are not found, or if they are often missing, the hypothesis is not entirely voided, but the evidence against it becomes serious.*

In the calculations it is assumed that the density of the solar atmosphere is small enough that each molecule may be assumed as independent of the others. In this case the forces due to each of the planets may be projected to get a resultant force in considering the tides raised. Forces do not appreciably affect the heights of tides along lines perpendicular to them, in such a case.

The square of the resultant force of the three planets at the point on the sun, where it is at any instant a maximum, is given by:

$$R^2=f_v^2+f_m^2+f_e^2+2f_mf_v\cos m+2f_ef_m\cos(e-m)+2f_ef_v\cos e.$$

In this equation f_v and f_e are the practically constant tidal forces of Venus and of the earth, the former taken as unity; f_m is the tidal force of Mercury, varying from 0.756 to 0.215, depending on its true anomaly; e is the angle between the earth and Venus and m is the angle between Mercury and Venus. The expression for the angle between Venus and the vector R is not needed in this work. It is stated merely for the sake of completeness.

$$\tan R=\frac{f_m\sin m+f_e\sin e}{f_v+f_m\cos m+f_e\cos e}$$

To express accurately the effects on it of each of the terms involved in R would require a series expansion, similar to that of general perturbations. However, we can very easily consider the magnitudes of the contributions to the square of R. Such are entirely sufficient for our purpose, since we need only the order of importance of the different terms. The numbers given doubly in parenthesis are the maximum and the minimum values of f_m.

$$R^2=1+\begin{Bmatrix}0.756\\0.215\end{Bmatrix}^2+0.451^2+2\begin{Bmatrix}0.756\\0.215\end{Bmatrix}\cos m$$
$$+0.902\begin{Bmatrix}0.756\\0.215\end{Bmatrix}\cos(e-m)+0.902\cos e$$

In the table below where the terms, or periods, are segregated the magnitudes stated are the contributions of the terms to the square of R.

Cause of term	Designation	Length of period	Magnitude
Mercury-Venus	A	72 d . 28	1.512 to 0.430.
Venus-earth	B	291. 96	0.902.
Mercury-earth	C	57. 94	0.451 times mag. of A.
Eccentricity of Mercury	D	87. 97	0.541.

The magnitudes of the contributions to R^2 show that only the first two terms, designated as A and B need be considered. The forces from these terms will average about the same, but the term B is of a period almost exactly four times as long as term A. For this reason we will expect its effect on the number of spots to be considerably greater than that of any of the other terms.

Obviously it is impossible to look for a small amplitude term of period 72.28 days with data which are monthly averages. Fortunately five-day averages, or more accurately, averages over one seventy-third of a year are available for the years 1876–1911. Doctor Elsa Frenkel (now Dagobert) in 1913 investigated, by means of Schuster's periodogram, the possibilities of short periods (5). She arrived at the conclusion that two highly variable periods exist, one of length averaging 68.5 days, the other in the neighborhood of 200 days. The method used, apparently showed the shorter to vary in length from 50 to 100 days. Ten-day averages are about the proper length for our search, accordingly means were made of each consecutive pair of her data. Since her paper is available, the data will not be reprinted here.

We are looking for terms of small amplitude, therefore we must choose the lags for the periodogram, such that there will be many products for each point computed. It was decided to compute a periodogram from lags, varying by two seventy-thirds of a year between 609 and 688 of such intervals. In this stretch we can compute the position of 11 crests of the A term and 2 crests of the B term. The number of products of data formed for each point varies from 705 for the 609 interval lag to 626 for the 688 interval lag. Even such a large number of products will leave accidental errors of somewhat troublesome proportions.

An interesting feature of any sharp peaks to be found in the periodogram, is that they must be followed at an interval of one rotation of the sun by a satellite. If to-day we were to observe an unusual number of sun spots, since many of them would persist, we would have another maximum in about 26 days, due to the adopted method of counting. Such a rotational pseudo period could easily be differentiated from a true one by the fact that after one or more rotations of the sun it would die out, and when such a period would show again in another part of the periodogram, it would bear no phase relationship to the former set, unless its primary were due to a real periodicity. On the other hand, peaks due to a real periodicity would follow regularly at intervals equal to the period length throughout the whole stretch of the periodogram. This last feature is one of the strongest advantages of the correlation periodogram in a search for periodicities.

The 292-day period is long enough that the variation due to the 11-year cycle will mask it, unless the latter is eliminated. The 72.28 day period, however, should show sharp peaks, displaced in the direction of ascent of the 11-year cycle. Each of these should be followed by a satellite. Since our smallest interval for the periodogram is 10 days, the satellites must follow sometimes at 20-day intervals and at others at 30-day intervals. If we find at approximately the computed places, the crests of the A term and find them followed at the proper intervals by their satellites, and if we find few or no peaks other than those computed in advance, the point will be established that the planetary tides are a major factor in production of sun spots. The divergence from such ideal conditions will mark the uncertainty of the conclusion. Afterward it will be necessary to eliminate the 11-year cycle from the results and see whether the 292-day period appears.

It would be natural to expect that if tides do affect the number of sun spots, the part of the sun undergoing the maximum tidal agitation would be that which would show the most spots. There are two such nearly equal areas opposite each other on the sun. If we had used 5-day means we would expect the peaks of the shorter terms to be fish-tailed with a separation of one-half a solar rotation. The 10-day means are nearly enough the half rotation

period that we will get merely a broadening and sometimes a displacement either way. This half rotation period can not extend to the interval at which the satellites follow, for they merely, in a lesser degree, retrace what has already occurred in the primary peak one rotation period earlier.

In this paper we are not interested in the actual correlation coefficients. It is sufficient to take terms which are proportional to them. The means of the products formed for each periodogram point are practically so proportional and can be computed in much less time than the coefficients themselves. The amount of work to be done in forming and adding more than 50,000 products is tremendous and any saving of time becomes worth while, so long as it can in no way invalidate the results.

The periodogram as computed, and without elimination of the 11-year term is given as Figure 2. The abscissæ are in units of two seventy-thirds of a year and the ordinates in means of the products used in forming the points. Since the lags vary from a little less than one and a half of the 11-year cycles to a little more, the means of the products are all very large negatives. An arrow, with the letter A over it, points to each place where a crest of the 11-year term has been computed and one with an S over it follows each A by 26 days, to indicate the computed position of its satellite.

Three misses are seen at a glance. The ones at 612 and 648 are extra peaks, the only ones in the whole periodogram. The one at 634 is, of course, a badly displaced A peak. The other 10 A peaks all fall sufficiently close to the computed positions to be called fits. Eight of these peaks come within one periodogram point of the computed positions and are, therefore, exact. Each of the 11 A peaks is followed by its satellite, in only one case at an interval different from the computed 20 to 30 days. The 612 and 648 peaks seem rather large to be accidental but no explanation of them has been found.

All that remains now is to eliminate the 11-year variation from the periodogram to see whether the 292-day period shows and whether its amplitude is greater than the 72-day, as it should be; and whether its crests fall at the proper places. Four times the A period is 289.12 days, almost exactly equal to the long 291.96-day period. If, therefore, we form averages of 29 consecutive points, both these periods are eliminated. Curvature of the 11-year cycle during this interval will cause the means not to fall exactly on the 11-year curve, but the errors caused are not large and can bear no possible relationship to the periods for which we are searching. These means can be subtracted from the periodogram points and will leave us any short variations. Changes in the curvature of the 11-year variation, during the stretch of the periodogram, will somewhat warp our resultant modified periodogram, but can neither introduce nor hide any significant features. Figure 3 is this modified periodogram. In it the A period and its satellites are marked as in the first figure. The computed crests for the B term are shown by arrows under that letter. Both fall in the proper places and the amplitude is found to be around two and a half times that of the 72-day term. The 648 peak now resembles a displaced A peak, rather than an extra one, as we considered it from the original periodogram.

The agreements between hypothesis and observation in this paper and in Brown's early paper are so excellent that there seems to be no question that planetary action, presumably tidal, is the principal controlling factor in the number of sunspots observed. This leads to several interesting speculations regarding the effects of tides of stars on the sun and of the light changes in certain variable stars. The periods considered in this paper have forces equal to those of the outer planets, yet they produce much smaller disturbances. Evidently the variation must continue through a few years if it is to show its maximum effect. Apparently, from the approximate agreement of magnitude ratios in Brown's calculations, periods of a length such as those of Jupiter and Saturn have time to get in their full effect. A star of mass equal to that of the sun would have to approach to within

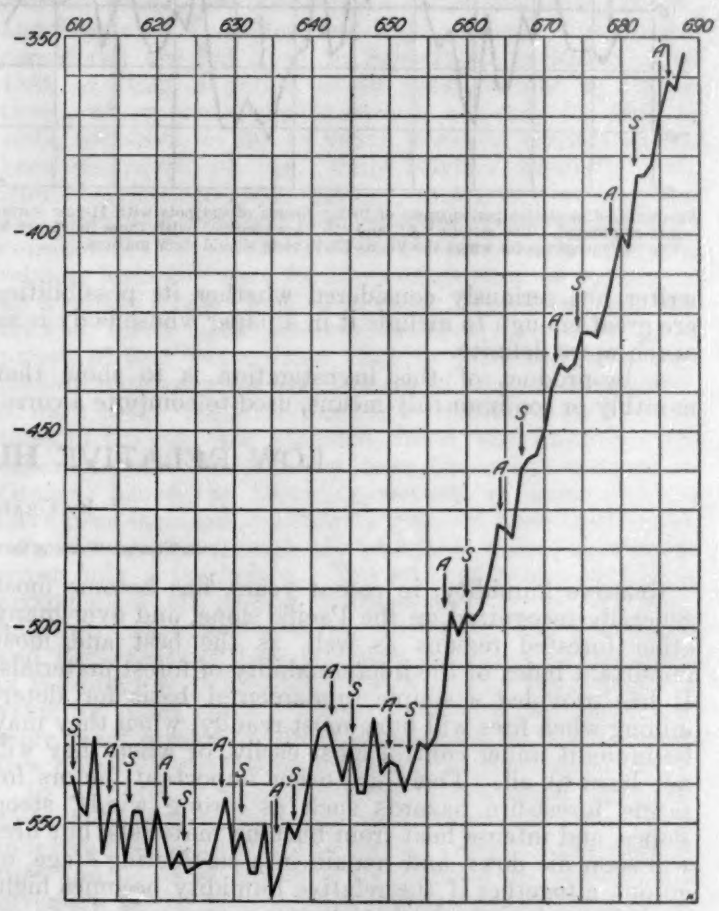

FIGURE 2.—Correlation periodogram of 10-day sun-spot means. The "A" arrows point to the positions where the Venus-Mercury tidal force should bring peaks according to theory. The "S" arrows point to the positions where the satellites of "A" should fall

53 astronomical units to have an equal tidal effect. This is about four thousand times as close as any star known at present. If the sun were distended to one thousand times its present radius, far larger than any known giant, the distance would still have to be four hundred times as close as Alpha Cantauri. Perhaps the writer is in error, for he is no authority on the subject, but he can not see that there would be any tidal difference in the cases of equilibrium due on the one hand to light pressure and gravitation and on the other hand to rotational speed and gravitation. It would seem to him that a star to have had an effect in the evolution of planets would have had to approach within an unreasonably small distance. Material left behind by a pulsating giant during its return from its maximum diameter would seem a more likely source of planetary material. Once the material for one such planet had gathered, it would begin to produce serious tidal disturbances on the giant and probably, for a time at least, cause more material to be lost and larger planets to be formed. Later, as the star contracted,

especially if its oscillations in diameter decreased, planets formed would be smaller. The subject matter of this paragraph is offered very tentatively, and the writer has seriously considered whether its possibilities are great enough to include it in a paper whose body is so much more definite.

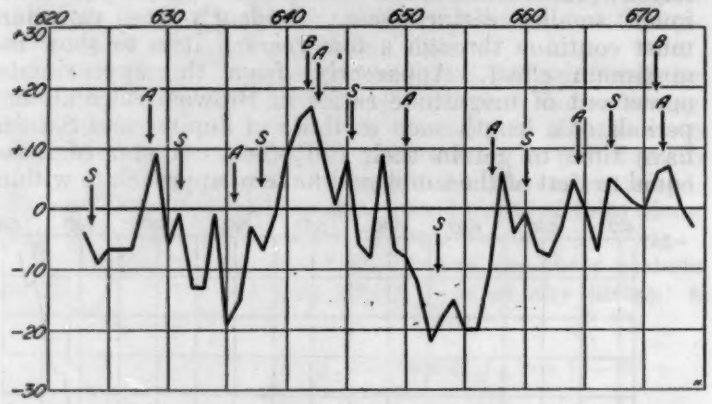

FIGURE 3.—Correlation periodogram of 10-day means of sunspots with 11-year variation eliminated. The arrows "A" and "S" are identical with those in Figure 2. The "B" arrows point where the Venus-Earth term should show maxima

A by-product of this investigation is to show that monthly or semimonthly means, used to compute a correlation periodogram, will in this manner locate the dates of sun-spot maxima and minima more accurately than do the methods now used. There is no single point to stand out and catch the eye, and the result depends upon a consideration of every variation in shape during the cycle.

A grant from the research committee of the Graduate School of the University of Kansas, under which the great majority of the computing was done by Mr. James Edson, is gratefully acknowledged.

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LOW RELATIVE HUMIDITY IN OREGON

By CHARLES I. DAGUE

[Fire-Weather Warning Service, Portland, Oreg., April 1, 1929]

Relative humidity, in recent years, has become most generally recognized on the Pacific slope, and over many other forested regions as well, as the best and most important index of the inflammability of forest materials. It has provided a simple fundamental basis for determining when fires will burn most readily, when they may be brought under control most easily, or when they will not burn at all. There are other important factors for rating forest-fire hazards such as strong winds, steep slopes, and intense heat from burning materials, but fires will soon die down and remain in a smoldering stage, or go out altogether if the relative humidity becomes high, regardless of wind, slope, or heat.

Past history of forest fires shows that the largest and most destructive fires have occurred, almost without exception, within a group of one to three days during a time when the relative humidity was low, regardless of whether or not the season as a whole was wet or dry. Present-day experiences with forest fires merely lend support to the fact that extreme forest-fire hazards are always the result of low relative humidity. Now it is these days, or groups of days, with low relative humidity that forest-fire protective organizations wish to anticipate so that they may more fully prepare their organizations to cope with any fire situation which may present itself on these days.

The importance of relative humidity as a controlling factor of forest-fire hazard is also indicated in the fact that the Logging Underwriting & Inspection Association writes a special policy containing a humidity warranty for logging risks whereby a logging operator is granted substantially reduced rates on the premium of his policy by agreeing to suspend all logging operations for any period that the relative humidity is 30 per cent or lower.

Since the special fire-weather warning service of the Weather Bureau was established in Oregon late in the season of 1924, fire-weather forecasts and warnings, embodying forecasts of relative humidity, winds, temperature, and thunderstorms, when thunderstorms are probable, have been issued twice daily, both morning and evening, throughout the greater portion of each season. The Weather Bureau, however, as long ago as 1913, began its fire-weather warning service on the Pacific coast by issuing forecasts that were known as fire-wind forecasts. Fire-weather forecasts, as they are known to-day, are available daily to the various forest-fire protective organizations, the logging operators, and to the public, by radio, the newspapers, and the printed weather map. Special fire-weather warnings of approaching spells of moderately low, low, or extremely low relative humidity are telegraphed to the State forester, district fire wardens, forest supervisors, and others whenever they are imminent. These special warnings are usually sent out by telegraph in the evening, the time of day when the protective organizations are most closely in touch with the personnel of their organizations, to provide them with ample opportunity for preparing beforehand for any possible emergencies that may arise. Only in an emergency, due to sudden changes in the weather, are the special fire-weather warnings ever sent out by telegraph in the morning.

The special fire-weather warnings, sent out by telegraph in Oregon, are received by 16 forest fire patrol associations, 5 State patrolled counties, 14 national forests, 2 Indian reservations, and 1 national park. They are also sent, upon request, to several logging operators who bear the cost of having these messages telegraphed. All of these organizations look after the dissemination, in their respective districts, of all fire-weather warnings telegraphed them by the Weather Bureau.

The length of the fire-weather season in the Pacific Northwest has been arbitrarily fixed, for convenience, to

include the months of April to September of each year. Precipitation then is at a minimum for the year, and there are frequent days, or groups of days, with low relative humidity. The peak of the fire-weather season usually occurs during the latter part of July or the first part of August. There are occasional days, or groups of days, with low relative humidity from October to March, but these months make up the wet season of the year when there is a maximum frequency of rainy days and the forests are generally quite wet, so that forest fires of any importance rarely ever occur. During the last two winter seasons, however, on February 23, 1928, and February 9, 1929, two small forest fires occurred along the west slope of the Coast Range. The fire on February 23, 1928, burned over an area of about 300 acres, starting in a large fern tract and burning through a large and thickly forested area before dying out. The fire on February 9, 1929, was farther south on the west slope of the Coast Range and was not so large. A fire also burned up a steep slope to its summit through old snags in Wind River Canyon in the State of Washington on February 23, 1928, the ground at the time being heavily covered with snow. The relative humidity was very low on both of these dates, and had been very low for a day or so previously.

West of the Cascade Range in the Douglas-fir region, where vegetation on the forest floor is dense and heavy, a dangerous forest-fire hazard is considered to exist whenever the relative humidity is 38 per cent or lower for any length of time. East of the Cascade Range in the yellow pine sections, where it is normally much drier and the vegetation on the forest floor much less than in the Douglas-fir regions, a lower relative humidity base 25 to 20 per cent or lower, is used for rating dangerous periods of forest-fire hazard. Over the extreme southwest part of the State, where a complex system of mountain ranges exists the vegetation on the forest floor largely partakes of the nature of that in the yellow-pine sections, but is somewhat heavier, so a relative humidity base of 25 per cent or lower is used for rating dangerous periods of forest fire hazard over this section of Oregon.

Observations of relative humidity are made at first-order Weather Bureau stations and are available as far back as the records for each station extend. Weather Bureau stations, however, even though within forested regions, are located in cities outside of the forests themselves, so the relative humidity records at these stations are not always entirely representative of the humidity changes and conditions prevailing within the forests themselves. These relative humidity records, nev rtheless, serve to give good conceptions of some of the humidity changes and conditions taking place within or near the forests in their respective localities. They have also been valuable to investigators for making correlations of past peak forest-fire occurrences with the relative humidities occurring at those time as recorded at these stations. In this way determinations were made of some of the reasons why so many forest fires should have occurred on a certain day or group of days and did not occur at other times. These investigations showed decisively that peak forest-fire occurrences in the past took place on a day or group of days when the relative humidity was low. It is these days, or group of days, with low relative humidity that forest-fire protective organizations wish to anticipate as far in advance as possible so that they may amply prepare their organizations to meet, promptly and effectively, any contingency that may arise. The United States Weather Bureau, endeavors to anticipate, so far as practicable, days with low relative humidity, and in this way its service has become an integral part of the protective systems of these organizations.

Tabular data, dealing with the occurrence and persistence of low relative humidity at the regular Weather Bureau stations in Oregon, and for two Weather Bureau stations in southern Washington near the Oregon-Washington boundary line, and therefore representative of weather conditions for these respective sections of northern Oregon, are presented in this paper. The Weather Bureau stations are North Head and Walla Walla, Wash., and Portland, Roseburg, and Baker, Oreg. The records considered are for April to September, inclusive, from 1889 to 1928, a period of 40 years, except at Baker, Oreg., where the available records are only for 1911 to 1928, inclusive, or for 18 years, previous records having been destroyed by fire. Only relative humidity data from observations made regularly at 5 p. m., one hundred and twentieth meridian time, at these stations have been considered. Included in each of these tables are also relative humidity data for three other stations in Oregon, at Medford, Bend, and Lakeview. The humidity records at these latter stations, however, are only for a period of four years, from 1925 to 1928, inclusive, and include data only for the months of May to September of each year. Relative humidity conditions for the sections of Oregon near Medford, Bend, and Lakeview are different from those shown near the other stations in Oregon, hence the humidity records at these stations have been included to set forth some of these contrasting conditions, even though the available humidity records cover only a few years. The type of tables and their arrangement are similar to those used by G. W. Alexander in connection with his article on The Frequency and Persistence of Low Relative Humidity in the State of Washington, published in the MONTHLY WEATHER REVIEW for April, 1928. Thus, those who so desire can more readily make a direct comparison of the low relative humidity conditions prevailing in the two States.

In the State of Washington the total number, the averages, and the monthly totals for all days below the upper index vary directly with the normal variation in temperature and hours of sunshine throughout the season, and inversely as the precipitation, except for all brackets at North Head and the two lower brackets at Portland, where the opposite is true. None of these abnormalities show for any of the stations for the eastern sections of the State. The abnormalities at North Head and the two lower brackets at Portland are developed by the HIGHS that occur with greater frequency and intensity over the plateau late in spring and early in autumn—in April, May, and September—than during the height of the fire-weather season in summer—in June, July, and August. These continental HIGHS of late spring and early autumn, being of greater intensity and importance, give rise to easterly winds that blow with considerably greater force than during the summer months and extend their continental influences over coastal regions for periods of from one to three days in succession, thereby displacing for the time all maritime influences by which the weather over the coastal regions of the State are normally controlled. The easterly winds of summer always produce a bad fire-weather situation west of the Cascade Range whenever they occur, but their influence rarely ever extends much beyond the eastern slope or summit of the coast range.

TABLE NO. 1.—*Total number of days with relative humidity as indicated (5 p. m. observation)*

Relative humidity (per cent)	April	May	June	July	August	September	Season
North Head, Wash. (1889–1928)							
50 to 41, inclusive	14	12	4	4	4	17	55
40 to 31, inclusive	8	3	0	1	2	19	33
30 or lower	5	3	3	0	1	10	22
Total, 50 or lower	27	18	7	5	7	46	110
Portland, Oreg. (1889–1928)							
38 to 31, inclusive	133	152	158	267	250	107	1,067
30 to 26, inclusive	57	68	69	84	80	43	410
25 to 20, inclusive	68	46	40	41	35	31	261
19 or lower	20	16	21	17	13	19	106
Total, 38 or lower	278	282	288	409	387	200	1,844
Roseburg, Oreg. (1889–1928)							
30 to 26, inclusive	87	116	130	215	208	121	877
25 to 20, inclusive	67	76	101	163	192	92	691
19 to 15, inclusive	21	21	29	63	50	32	216
14 or lower	4	4	8	16	12	4	48
Total, 30 or lower	179	217	268	457	462	249	1,832
Walla Walla, Wash. (1889–1928)							
25 to 20, inclusive	126	170	215	309	308	153	1,281
19 to 15, inclusive	48	68	142	265	264	62	849
14 or lower	16	19	49	187	129	15	415
Total, 25 or lower	190	257	406	761	701	230	2,545
Baker, Oreg. (1911–1928)							
25 to 20, inclusive	61	75	59	114	125	80	514
19 to 15, inclusive	13	25	19	61	76	54	248
14 or lower	4	9	12	37	41	25	128
Total, 25 or lower	78	109	90	212	242	159	890
Medford, Oreg. (1925–1928)							
30 to 26, inclusive	-----	32	25	29	28	10	124
25 to 20, inclusive	-----	11	15	46	48	14	134
19 to 15, inclusive	-----	2	3	18	14	3	40
14 or lower	-----	0	0	1	2	1	4
Total, 30 or lower	-----	45	43	94	92	28	302
Bend, Oreg. (1925–1928)							
25 to 20, inclusive	-----	9	27	44	29	12	-----
19 to 15, inclusive	-----	10	16	22	36	12	-----
14 or lower	-----	2	3	8	6	5	-----
Total, 25 or lower	-----	21	46	74	71	29	-----
Lakeview, Oreg. (1925–1928)							
25 to 20, inclusive	-----	10	22	15	17	19	-----
19 to 15, inclusive	-----	6	17	38	33	15	-----
14 to 11, inclusive	-----	0	13	34	28	12	-----
10 or lower	-----	0	1	25	29	16	-----
Total, 25 or lower	-----	16	53	112	107	62	-----

Records for May at Bend and Lakeview for 1927 and 1928 only.
Records for June at Bend and Lakeview for 1926 to 1928, inclusive.

TABLE NO. 2.—*Average number of days with relative humidity as indicated, monthly and for the season, with season extremes*

Relative humidity (per cent)	April	May	June	July	August	September	Season	Greatest number	Year	Least number	Year
North Head, Wash. (1889–1928)											
50 to 41, inclusive	0.38	0.32	0.11	0.11	0.11	0.45	1.48	5	1896	0	(1)
40 to 31, inclusive	.22	.09	.00	.03	.05	.50	.89	6	1926	0	(1)
30 or lower	.13	.08	.08	.00	.03	.26	.58	3	1922	0	(1)
Total, 50 or lower	.73	.49	.19	.14	.19	1.21	2.95	9	1926	0	(1)
Portland, Oreg. (1889–1928)											
38 to 31, inclusive	3.3	3.8	4.0	6.7	6.2	2.7	26.8	40	1904, 1919	14	1925
30 to 26, inclusive	1.4	1.7	1.7	2.1	2.2	1.1	10.2	15	[2]1890	4	1899, 1901
25 to 20, inclusive	1.7	1.2	1.0	1.0	.9	.8	6.6	16	1918	1	1903, 1925
19, or lower	.5	.4	.5	.4	.3	.5	2.6	8	1895	0	[2]1899
Total, 38 or lower	6.9	7.1	7.2	10.2	9.7	5.1	46.2	73	1918	22	1925
Roseburg, Oreg. (1889–1928)											
30 to 26, inclusive	2.3	3.0	3.3	5.4	5.2	3.0	22.2	38	1922	11	1901
25 to 20, inclusive	1.6	1.9	2.6	4.1	4.8	2.3	17.3	37	1926	7	1913
19 to 15, inclusive	.6	.6	.8	1.6	1.2	.8	5.6	15	1918	1	[2]1891
14, or lower	.1	.1	.2	.4	.3	.1	1.2	10	1924	0	[2]1890
Total, 30 or lower	4.6	5.6	6.9	11.5	11.5	6.2	46.3	80	1924	26	1894
Walla Walla, Wash. (1889–1928)											
25 to 20, inclusive	3.1	4.2	5.4	7.7	7.7	3.8	32.0	51	1921	5	1902
19 to 15, inclusive	1.2	1.7	3.6	6.6	6.6	1.6	21.2	48	1890	1	1902
14, or lower	.4	.5	1.2	4.7	3.2	.4	10.4	37	1889	0	(1)
Total, 25 or lower	4.7	6.4	10.2	19.0	17.5	5.8	63.6	109	1910	6	1902
Baker, Oreg. (1911–1928)											
25 to 20, inclusive	3.4	4.2	3.2	6.3	6.9	4.4	28.4	43	1928	18	1925
19 to 15, inclusive	.7	1.4	1.1	3.4	4.2	3.0	13.8	32	1924	3	1918
14, or lower	.2	.5	.7	2.1	2.3	1.4	7.2	27	1924	1	[2]1912
Total, 25 or lower	4.3	6.1	5.0	11.8	13.4	8.8	49.4	100	1924	25	1925
Medford, Oreg. (1925–1928)											
30 to 26, inclusive	-----	8.0	6.2	7.3	7.0	2.5	31.0	36	1928	25	1927
25 to 20, inclusive	-----	2.7	3.8	11.5	12.0	3.5	33.5	38	1925	31	1927
19 to 15, inclusive	-----	.5	.8	4.5	3.5	.8	10.1	17	1928	3	1926
14, or lower	-----	.0	.0	.2	.5	.2	.9	2	1928	0	1926, 1927
Total, 30 or lower	-----	11.2	10.8	23.5	23.0	7.0	75.5	89	1928	64	1927
Bend, Oreg. (1925–1928)											
25 to 20, inclusive	-----	4.5	9.0	11.0	7.2	3.0	34.7	41	1926	32	1927, 1928
19 to 15, inclusive	-----	5.0	5.3	5.5	9.0	3.0	27.8	46	1928	18	1927
14, or lower	-----	1.0	1.0	2.0	1.5	1.2	6.7	15	1928	3	1927
Total, 25 or lower	-----	10.5	15.3	18.5	17.7	7.2	69.2	93	1928	53	1927
Lakeview, Oreg. (1925–1928)											
25 to 20, inclusive	-----	5.0	7.3	3.8	4.2	4.7	25.4	28	1928	21	1927
19 to 15, inclusive	-----	3.0	5.7	9.5	8.3	3.8	30.3	35	1927	30	1928
14 to 11, inclusive	-----	0.0	4.3	8.5	7.0	3.0	23.3	35	1926	14	1927
10, or lower	-----	.0	.3	6.2	7.3	4.0	17.3	27	1926	11	1927
Total, 25 or lower	-----	8.0	17.6	28.0	26.8	15.5	95.9	108	1928	81	1927

[1] Several seasons. [2] Et al.

Records for May at Bend and Lakeview only for 1927 and 1928.
Records for June at Bend and Lakeview only for 1926 to 1928, inclusive.

The severity of any dangerous period of fire-weather depends upon the number of hours during a day, or the number of consecutive days, with low relative humidity. Frequently, there are single days during the season when the relative humidity has been near, or below the point which is considered dangerous for only a short time, in which event the fire hazard for any of these days is naturally small. If the relative humidity has been near or below the danger point for several hours, the fire hazard becomes greater and care with fire must be exercised. When the relative humidity has been low for two or more consecutive days, the fire hazard becomes extremely dangerous so that all precautions must be taken to prevent fire, even to the closing down of all operations within the forests, if necessary. Table 3 shows the tendency of the occurrence or recurrence of days with low relative humidity at each of these stations. Tables 4 and 5 are recapitulations of Table 3 to show the average number of periods, in groups of one or more days, of low relative humidity, and the average duration, in days, of periods of low relative humidity, with the duration and date of the longest period on record.

Table 6 is a chronological list of the number of days of low relative humidity, within the limits indicated, during each season for each of the stations whose records are being reviewed.

TABLE No. 3.—*Groups of days with relative humidity*

ROSEBURG, OREG. (1889–1928)

Days	1	2	3	4	5	6	7	8	9	10	11	12	13	14
30 per cent or lower														
April	49	21	12	10	1	0	1	1	0	0	0	0	0	....
May	69	26	11	7	3	1	0	1	0	0	0	0	0	....
June	51	27	10	8	6	3	2	2	0	1	1	1	0	....
July	70	32	23	16	5	9	4	5	0	2	0	0	0	....
August	72	47	26	10	7	5	5	4	1	0	1	0	3	....
September	53	33	15	7	6	1	0	2	0	0	0	0	0	....
Season	364	186	97	58	28	19	12	15	1	3	2	1	3	....
25 per cent or lower														
April	34	11	7	4	1	0	0	0	0	0	0	0	....	....
May	54	9	3	1	2	0	0	0	0	0	0	0	....	....
June	42	21	8	0	2	2	0	1	1	0	0	0	....	....
July	59	27	15	9	4	2	0	0	0	0	0	0	....	....
August	85	26	14	2	4	4	2	0	1	0	0	1	....	....
September	40	21	5	3	1	0	0	1	0	0	0	0	....	....
Season	314	115	52	19	14	8	2	2	2	0	0	1	....	....
19 per cent or lower														
April	17	4	0	0	....	....	....	....	....	....	....	....	....	....
May	17	3	0	1	....	....	....	....	....	....	....	....	....	....
June	16	7	2	0	....	....	....	....	....	....	....	....	....	....
July	32	15	3	1	....	....	....	....	....	....	....	....	....	....
August	36	5	4	1	....	....	....	....	....	....	....	....	....	....
September	18	7	1	0	....	....	....	....	....	....	....	....	....	....
Season	136	41	10	3	....	....	....	....	....	....	....	....	....	....
14 per cent or lower														
April	4	0	....	....	....	....	....	....	....	....	....	....	....	....
May	2	1	....	....	....	....	....	....	....	....	....	....	....	....
June	3	3	....	....	....	....	....	....	....	....	....	....	....	....
July	14	1	....	....	....	....	....	....	....	....	....	....	....	....
August	12	0	....	....	....	....	....	....	....	....	....	....	....	....
September	3	1	....	....	....	....	....	....	....	....	....	....	....	....
Season	38	6	....	....	....	....	....	....	....	....	....	....	....	....

TABLE No. 3.—*Groups of days with relative humidity*—Continued

BAKER, OREG. (1911–1928)

Days	1	2	3	4	5	6	7	8	9	10	11	12	13	14
25 per cent or lower														
April	20	13	5	3	0	1	0	0	0	0	0	0	0	0
May	24	14	8	1	1	0	1	2	0	0	0	0	0	0
June	28	9	8	3	2	0	0	0	0	0	0	0	0	0
July	33	15	12	6	2	4	2	3	0	2	0	0	0	0
August	37	13	8	7	9	2	3	0	1	1	0	2	0	1
September	36	21	7	4	0	3	0	0	1	1	0	0	0	0
Season	178	85	48	24	14	10	6	5	2	4	0	2	0	1
19 per cent or lower														
April	13	2	0	0	0	0	0	0	0	....	....	....	....	....
May	14	6	0	2	0	0	0	0	0	....	....	....	....	....
June	16	2	2	0	0	0	0	0	0	....	....	....	....	....
July	28	19	1	2	2	0	0	1	0	....	....	....	....	....
August	31	13	4	4	2	1	1	0	1	....	....	....	....	....
September	38	7	7	0	0	0	1	0	0	....	....	....	....	....
Season	140	49	14	8	4	1	2	1	1	....	....	....	....	....
14 per cent or lower														
April	4	0	0	....	....	....	....	....	....	....	....	....	....	....
May	6	1	0	....	....	....	....	....	....	....	....	....	....	....
June	7	2	1	....	....	....	....	....	....	....	....	....	....	....
July	26	4	1	....	....	....	....	....	....	....	....	....	....	....
August	23	5	3	....	....	....	....	....	....	....	....	....	....	....
September	19	3	0	....	....	....	....	....	....	....	....	....	....	....
Season	85	15	5	....	....	....	....	....	....	....	....	....	....	....

NORTH HEAD, WASH. (1889–1928)

Days	1	2	3	4	5	6	7	8	9	10	11	12	13	14
50 per cent or lower														
April	15	6	0	0	....	....	....	....	....	....	....	....	....	....
May	14	2	0	0	....	....	....	....	....	....	....	....	....	....
June	7	0	0	0	....	....	....	....	....	....	....	....	....	....
July	5	0	0	0	....	....	....	....	....	....	....	....	....	....
August	4	1	0	0	....	....	....	....	....	....	....	....	....	....
September	24	9	0	1	....	....	....	....	....	....	....	....	....	....
Season	69	18	0	1	....	....	....	....	....	....	....	....	....	....
40 per cent or lower														
April	9	2	0	0	....	....	....	....	....	....	....	....	....	....
May	2	2	0	0	....	....	....	....	....	....	....	....	....	....
June	3	0	0	0	....	....	....	....	....	....	....	....	....	....
July	1	0	0	0	....	....	....	....	....	....	....	....	....	....
August	3	0	0	0	....	....	....	....	....	....	....	....	....	....
September	18	3	0	1	....	....	....	....	....	....	....	....	....	....
Season	36	7	0	1	....	....	....	....	....	....	....	....	....	....
30 per cent or lower														
April	3	1	....	....	....	....	....	....	....	....	....	....	....	....
May	1	1	....	....	....	....	....	....	....	....	....	....	....	....
June	3	0	....	....	....	....	....	....	....	....	....	....	....	....
July	0	0	....	....	....	....	....	....	....	....	....	....	....	....
August	1	0	....	....	....	....	....	....	....	....	....	....	....	....
September	10	0	....	....	....	....	....	....	....	....	....	....	....	....
Season	18	2	....	....	....	....	....	....	....	....	....	....	....	....

PORTLAND, OREG. (1889–1928)

Days	1	2	3	4	5	6	7	8	9	10	11	12	13	14
38 per cent or lower														
April	63	36	14	11	6	2	2	0	1	0	0	....	....	....
May	71	34	19	9	4	3	1	0	1	0	0	....	....	....
June	60	30	19	11	3	2	3	1	2	0	0	....	....	....
July	75	46	36	7	8	6	3	0	0	1	0	....	....	....
August	76	43	29	14	4	2	3	2	0	0	1	....	....	....
September	57	30	11	5	2	1	1	0	0	0	0	....	....	....
Season	402	219	128	57	27	16	13	3	4	1	1	....	....	....

TABLE No. 3.—*Groups of days with relative humidity*—Continued

PORTLAND, OREG. (1889-1928)

Days	1	2	3	4	5	6	7	8	9	10	11	12	13	14
30 per cent or lower														
April	39	18	10	6	1	2	0							
May	35	27	8	3	1	0	0							
June	47	14	10	4	0	1	1							
July	66	19	5	4	1	0	0							
August	61	20	7	2	0	1	0							
September	41	14	3	2	1	0	0							
Season	289	112	43	21	4	4	1							
25 per cent or lower														
April	32	15	7	1										
May	29	12	1	2										
June	38	6	4	1										
July	35	8	2	0										
August	28	5	1	1										
September	23	9	3	0										
Season	185	55	18	5										
19 per cent or lower														
April	11	4	0											
May	8	4	0											
June	13	2	1											
July	14	1	0											
August	11	1	0											
September	11	4	0											
Season	68	16	1											

TABLE No. 3a.—*Groups of days with relative humidity*

WALLA WALLA, WASH. (1889-1928)

Days	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	22	25	29	39	42
25 per cent or lower																							
April	49	19	11	7	3	2	1	1															
May	55	27	14	10	4	4	2	2	1														
June	40	29	13	6	9	7	5	4	4	0	0	0	0	2	1	0	2						
July	39	22	15	14	8	5	9	9	3	3	4	3	1	1	3	2	1	1	1	2	1	1	1
August	48	20	18	9	11	5	9	3	4	5	0	0	3	0	2	1	0	1	0	1			
September	62	22	8	6	4	0	1	2	0	0	1												
Season	293	139	79	52	39	23	27	21	12	8	5	3	4	3	6	3	3	2	1	3	1	1	1
19 per cent or lower																							
April	30	8	2	3																			
May	35	12	9	1																			
June	43	16	16	5	4	2	2	1	0	1													
July	69	25	14	11	4	4	3	6	1	3	4	0	0	0	2	1							
August	73	28	19	10	12	2	4	3	1	1	0	1											
September	29	12	4	1	2																		
Season	279	101	64	31	22	8	9	10	2	5	4	1	0	0	2	1							
14 per cent or lower																							
April	11	1	0	1																			
May	11	4																					
June	25	7	1	1																			
July	54	13	10	3	5	3	2	1															
August	57	17	8	3																			
September	11	1																					
Season	169	43	19	8	5	3	2	1															

TABLE No. 3b.—*Groups of days with relative humidity*

MEDFORD, OREG. (1925-1928)

Days	1	2	3	4	5	6	7	8	9	10	11	13	14	16	18	20	21	26
30 per cent or lower																		
May	10	6	4	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0
June	10	1	3	1	1	2	0	0	0	0	0	0	0	0	0	0	0	0
July	2	4	2	0	1	0	0	0	0	0	1	0	0	1	1	1	1	1
August	3	1	3	1	1	0	0	0	0	0	1	1	0	1	0	0	0	0
September	3	3	0	1	1	0	0	0	0	0	0	0	1	0	0	0	0	0
Season	28	15	12	3	6	2	0	0	0	0	1	2	1	1	1	1	1	1
25 per cent or lower																		
May	7	3	0	0	0	0	0	0	0	0	0							
June	4	2	0	0	2	0	0	0	0	0	0							
July	8	7	1	3	0	0	0	2	0	0	1							
August	9	5	4	1	0	0	1	0	1	1	1							
September	1	0	0	1	1	0	0	0	–1	0	0							
Season	29	17	5	5	3	0	1	2		1	2							
19 per cent or lower																		
May	2	0	0	0														
June	2	1	0	0														
July	7	4	0	1														
August	10	0	2	0														
September	2	1	0	0														
Season	23	6	2	1														
14 per cent or lower																		
May	0																	
June	0																	
July	1																	
August	2																	
September	1																	
Season	4																	

TABLE No. 3c.—*Groups of days with relative humidity*

BEND, OREG. (1925-1928)

Days	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
25 per cent or lower															
May	4	0	1	1	0	0	0	0	0	0	1	0	0	0	0
June	5	4	2	1	0	0	0	0	0	0	0	1	0	0	1
July	7	2	2	1	4	0	1	0	0	1	0	0	0	1	0
August	3	3	2	0	2	1	0	0	2	0	0	0	0	0	1
September	10	2	1	1	0	0	0	0	0	0	1	0	0	0	0
Season	29	11	8	4	6	1	1	0	2	1	2	1	0	1	2
19 per cent or lower															
May	1	1	2	1	0	0	0	0	0	0	0				
June	6	3	1	1	0	0	0	0	0	0	0				
July	7	3	1	1	2	0	0	0	0	0	0				
August	10	2	1	2	1	1	0	0	0	0	0				
September	6	2	0	0	0	0	0	0	0	0	1				
Season	30	11	5	5	3	1	0	0	0	0	1				
14 per cent or lower															
May	0	1	0												
June	3	0	0												
July	1	2	1												
August	2	2	0												
September	1	2	0												
Season	7	7	1												

TABLE No. 3d.—*Groups of days with relative humidity*

LAKEVIEW, OREG. (1925-1928)

Days	1	2	3	4	5	6	7	8	9	10	13	14	15	18	19	25	27	28	37
25 per cent or lower																			
May	4	2	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
June	3	0	2	0	1	1	2	1	0	0	0	0	0	0	0	0	0	0	0
July	0	1	1	0	0	0	0	0	0	0	1	0	0	0	1	0	0	1	0
August	0	0	1	1	0	1	0	1	0	0	0	1	0	2	0	0	0	0	1
September	2	1	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
Season	9	4	4	4	1	2	2	2	0	0	1	1	1	2	1	1	0	1	1
19 per cent or lower																			
May	4	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	---	---
June	5	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	---	---
July	6	6	2	1	1	0	0	1	1	1	0	0	0	0	0	0	1	---	---
August	7	2	3	2	0	1	0	2	0	0	1	0	0	0	1	0	0	---	---
September	8	1	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	---	---
Season	30	11	5	3	2	2	0	3	2	1	1	0	0	0	1	0	1	---	---
14 per cent or lower																			
May	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	---	---	---	---
June	7	0	0	0	0	0	1	0	0	0	0	0	0	0	0	---	---	---	---
July	11	5	3	1	0	1	0	2	0	0	0	0	0	0	0	---	---	---	---
August	9	0	2	3	3	0	0	0	0	0	0	0	0	0	1	---	---	---	---
September	5	2	0	0	0	2	0	0	0	1	0	0	0	0	0	---	---	---	---
Season	32	7	5	4	3	3	1	2	0	1	0	0	0	0	1	---	---	---	---
10 per cent or lower																			
May	0	0	0	0	0	0	0	0	---	---	---	---	---	---	---	---	---	---	---
June	1	0	0	0	0	0	0	0	---	---	---	---	---	---	---	---	---	---	---
July	14	3	1	1	0	0	0	0	---	---	---	---	---	---	---	---	---	---	---
August	5	3	0	2	0	0	0	1	---	---	---	---	---	---	---	---	---	---	---
September	5	0	0	3	0	0	0	0	---	---	---	---	---	---	---	---	---	---	---
Season	25	6	1	6	0	0	0	1	---	---	---	---	---	---	---	---	---	---	---

Late in the season of 1924, through cooperation with the forest fire protective organizations of Oregon, steps were taken to have daily observations of relative humidity and other pertinent weather data made regularly within the forests of the State in an intensive manner for the balance of the season. This cooperation with the protective organizations has been subsequently maintained in the succeeding fire-weather seasons, but has been materially expanded to include a large number of logging operators. In this way, a large amount of data on relative humidity has been acquired from within the forests which has given the fire-weather forecaster a far more comprehensive conception of the relative humidity changes going on within the forests themselves. This greater knowledge of the relative humidity changes going on within the forests places the forecaster in a better position of forecasting these changes and he is able to render the protective organizations a greater and more valuable service.

Regular observations of relative humidity, made only with sling psychrometers, were received from 46 observers during the past season. Similar reports were also received from 22 other observers, together with the hygrothermograms from hygrothermographs which these observers also have as additional instrument equipment. Hygrothermograms were also received regularly from 29 other hygrothermographs, 18 of which are owned by logging operators, operating principally over the northwest portion of Oregon where most of the logging activities of the State are centered. The observations taken with sling psychrometers are principally available without interruption from the latter part of June through July and August to the first part of September of each season, while the hygro-thermograph records generally cover a longer period of each season from some time in April or May until the latter part of September.

Using only the lowest daily relative humidity taken regularly with sling psychrometers, supplemented by hygrothermograph records wherever they are needed to complete the relative humidity survey for a State subdivision, the average frequency of days with low relative humidity, within certain limits, for the two months of July and August for the four seasons, 1925 to 1928, has been compiled for 75 cooperating stations. These stations have been grouped into eight State subdivisions as in Table 7. Table 7 shows the average frequency of days with low relative humidity, within the limits indicated, for each subdivision, also the number of stations reporting within each subdivision and their average elevation.

It is interesting to note the gradual increase in the number of days with low relative humidity during July and August from the coast eastward to the west slope of the Cascade Range and eastern Oregon. Relative humidities of 20 per cent, or lower, rarely ever occur in the Willamette Valley and westward to the coast during these two months, but they do occur several days each season near and along the west slope of the Cascade Range. Low relative humidities occur with greater frequency along the lower portions of the west slope of the Cascade Range than along its upper portions, except near gaps in the summit which permit the drier air from east of the mountains to drift to the west side for short distances without much hindrance. The lowest relative humidity recorded in western Oregon occurred at Herman Creek Ranger Station in the Columbia River Gorge on July 23, 1927. In eastern Oregon, where the weather is normally warmer and drier and the absolute humidity content of the air is lower, the frequency of days with low relative humidity increases and normal relative humitities average decidedly lower than over western Oregon.

TABLE NO. 4.—*The average number of periods (groups of 1 or more days) of low relative humidity*

Relative humidity (per cent)	April	May	June	July	August	September	Season
North Head, Wash. (1889–1928)							
50 or lower	0.57	0.43	0.19	0.14	0.13	0.88	2.34
40 or lower	.30	.11	.08	.03	.08	.58	1.18
30 or lower	.11	.05	.08	.00	.03	.26	.53
Portland, Oreg. (1889–1928)							
38 or lower	3.4	3.6	3.3	4.6	4.4	2.7	21.8
30 or lower	1.9	1.8	1.9	2.4	2.3	1.5	11.8
25 or lower	1.4	1.1	1.2	1.1	.9	.9	6.6
19 or lower	.4	.3	.4	.4	.3	.4	2.1
Roseburg, Oreg. (1889–1928)							
30 or lower	2.4	3.0	2.8	4.2	4.5	2.9	19.7
25 or lower	1.4	1.7	1.9	2.9	3.5	1.8	13.2
19 or lower	.5	.5	.6	1.3	1.2	.6	4.8
14 or lower	.1	.1	.2	.4	.3	.1	1.1
Walla Walla, Wash. (1889–1928)							
25 or lower	2.6	3.0	3.0	3.7	3.5	2.6	18.2
19 or lower	1.1	1.4	2.2	3.7	3.8	1.2	13.5
14 or lower	.3	.4	.8	2.3	2.1	.3	6.2
Baker, Oreg. (1911–1928)							
25 or lower	2.3	2.8	2.8	4.4	4.7	4.1	21.1
19 or lower	.8	1.2	1.1	2.9	3.2	2.9	12.2
14 or lower	.2	.4	.6	1.7	1.7	1.2	5.8
Medford, Oreg. (1925–1928)							
30 or lower	5.5	4.5	3.5	3.0	2.2		18.8
25 or lower	2.5	2.0	5.5	5.5	1.0		16.5
19 or lower	.5	.8	3.0	3.0	.8		8.0
14 or lower	0.0	0.0	.2	.5	.3		1.0
Bend, Oreg. (1925–1928)							
25 or lower	3.5	4.7	4.8	3.5	3.8		20.3
19 or lower	2.5	3.7	3.5	4.2	2.2		16.2
14 or lower	.5	1.0	1.0	1.0	.8		4.4
Lakeview, Oreg. (1925–1928)							
25 or lower	4.0	3.3	1.5	2.0	1.2		10.9
19 or lower	2.5	2.3	5.0	4.8	2.8		18.2
14 or lower	0.0	2.7	5.8	4.5	2.5		17.4
10 or lower	0.0	.3	4.8	2.8	2.0		11.5

TABLE NO. 5.—*The average duration in days of periods of low relative humidity, with date and duration of longest period*

Relative humidity (per cent)	April	May	June	July	August	September	Season	Longest period with date
North Head, Wash. (1889–1928)								
50 or lower	1.3	1.1	1.0	1.0	1.2	1.4	1.2	4, September, 1926.
40 or lower	1.3	1.5	1.0	1.0	1.0	1.1	1.2	4, September, 1926.
30 or lower	1.2	1.5	1.0	0.0	1.0	1.0	1.1	2, April, 1928, and May, 1922.
Portland, Oreg. (1889–1928)								
38 or lower	2.1	2.0	2.3	2.3	2.2	1.8	2.1	11, August, 1923.
30 or lower	1.9	1.8	1.7	1.5	1.5	1.5	1.6	7, June, 1898.
25 or lower	1.4	1.5	1.3	1.3	1.3	1.4	1.4	4, several dates.
19 or lower	1.3	1.3	1.2	1.1	1.1	1.3	1.2	3, June, 1920.
Roseburg, Oreg. (1889–1928)								
30 or lower	2.0	1.8	2.5	2.6	2.6	2.1	2.3	13, August, 1908–18–20.
25 or lower	1.7	1.4	1.9	1.9	1.9	1.7	1.8	12, August, 1908.
19 or lower	1.2	1.3	1.3	1.4	1.3	1.3	1.4	4, several dates.
14 or lower	1.0	1.3	1.5	1.1	1.0	1.2	1.1	2, several dates.
Walla Walla, Wash. (1889–1928)								
25 or lower	2.0	2.3	3.5	5.7	4.0	2.0	3.4	42, July–August, 1910.
19 or lower	1.5	1.6	2.3	3.1	2.5	1.6	2.4	16, July, 1911.
14 or lower	1.3	1.3	1.4	2.1	1.5	1.1	1.6	8, July, 1911.
Baker, Oreg. (1911–1928)								
25 or lower	1.9	2.1	1.8	2.7	3.0	2.1	2.4	14, August, 1924.
19 or lower	1.1	1.5	1.3	1.8	2.1	1.5	1.7	9, August, 1924.
14 or lower	1.0	1.1	1.4	1.2	1.4	1.1	1.2	3, several dates.
Medford, Oreg. (1925–1928)								
30 or lower		2.0	2.3	8.5	5.2	3.6	4.0	26, July, 1927.
25 or lower		1.3	2.2	2.9	2.9	4.8	2.7	11, July, 1928, and August, 1927.
19 or lower		1.0	1.3	1.6	1.3	1.3	1.5	4, July, 1928.
14 or lower		0.0	0.0	1.0	1.0	1.0	1.0	1, several dates.
Bend, Oreg. (1925–1928)								
25 or lower		3.1	3.6	2.7	4.6	2.1	3.5	15, June, 1926, and August, 1928.
19 or lower		2.0	1.7	2.1	2.1	2.3	2.1	11, August–September, 1928.
14 or lower		2.0	1.0	2.0	1.5	1.7	1.6	3, July, 1928.
Lakeview, Oreg. (1925–1928)								
25 or lower		2.0	4.2	15.0	13.5	4.6	7.5	37, August–September, 1928.
19 or lower		1.2	1.7	4.8	4.2	2.3	3.4	27, July, 1928.
14 or lower		0.0	1.7	2.4	3.4	3.1	2.7	19, August, 1926.
10 or lower		0.0	1.0	1.4	2.4	2.1	1.8	8, August, 1926.

TABLE No. 6.—*Number of days with low relative humidity, within the limits indicated, for each season.* (*April to September, inclusive*)

Year	North Head, Wash.				Portland, Oreg.					Roseburg, Oreg.					Walla Walla, Wash.				Baker, Oreg.			
	50-41	40-31	30	Total	38-31	30-26	25-20	19	Total	30-26	25-20	19-15	14	Total	25-20	19-15	14	Total	25-20	19-15	14	Total
1889	4	2	1	7	29	10	8	2	49						34	29	37	100				
1890	2	0	0	2	31	15	8	1	55	20	10	2	0	32	40	48	17	105				
1891	2	0	0	2	22	9	6	2	39	30	12	1	0	43	37	24	17	78				
1892	1	0	0	1	24	12	11	2	49	20	18	2	0	40	30	14	3	47				
1893	2	0	1	3	23	6	3	2	34	20	10	1	0	31	17	3	1	21				
1894	2	1	1	4	26	9	3	1	39	15	8	3	0	26	34	13	4	51				
1895	3	0	0	3	30	14	12	8	64	29	16	3	0	48	39	23	3	65				
1896	5	3	0	8	23	15	7	3	48	21	10	6	1	38	18	4	2	24				
1897	2	1	1	4	29	15	10	5	59	24	12	3	0	39	37	11	2	50				
1898	2	0	1	3	23	15	13	7	58	18	12	7	0	37	23	2	1	26				
1899	1	2	0	3	24	4	4	0	32	18	9	2	0	29	20	13	8	41				
1900	1	0	0	1	22	7	2	2	33	20	10	1	0	31	18	9	0	27				
1901	2	0	1	3	18	4	4	1	27	11	20	10	0	41	11	2	0	13				
1902	2	0	1	3	32	8	2	6	48	22	11	5	0	38	5	1	0	6				
1903	1	0	1	2	26	10	1	1	38	14	17	3	0	34	16	5	1	22				
1904	2	0	0	2	40	10	11	6	67	20	22	6	2	50	28	4	0	32				
1905	3	1	1	5	35	7	6	4	52	17	25	4	0	46	21	11	3	35				
1906	2	0	0	2	37	10	7	2	56	18	16	1	0	35	22	12	2	36				
1907	0	1	1	2	30	11	8	5	54	14	20	3	0	37	37	13	2	52				
1908	0	0	0	0	20	6	3	0	29	19	25	4	0	48	35	27	16	78				
1909	1	0	0	1	21	11	7	2	41	28	21	8	1	58	37	34	27	98				
1910	1	1	0	2	27	12	3	0	42	23	14	3	0	40	46	30	33	109				
1911	1	0	0	1	16	5	7	3	31	21	16	5	1	43	39	26	29	94	31	17	10	58
1912	0	3	0	3	16	8	3	0	27	18	13	1	2	34	36	27	8	71	22	10	1	33
1913	0	2	1	3	22	7	2	0	31	18	7	2	1	28	42	34	10	86	20	14	4	38
1914	1	0	0	1	30	12	3	1	46	24	20	6	1	51	27	33	16	76	24	20	11	55
1915	0	0	0	0	32	5	6	0	43	19	16	5	0	40	42	26	12	80	33	11	12	56
1916	0	1	1	2	29	12	6	7	52	18	12	3	2	35	35	15	4	54	33	8	3	44
1917	1	0	0	1	29	15	6	1	51	20	18	9	2	49	33	29	18	80	25	13	6	44
1918	3	0	0	3	29	21	16	7	73	30	25	15	6	76	50	31	8	89	26	3	3	32
1919	3	2	0	5	40	14	11	6	71	27	23	12	2	64	46	29	17	92	34	26	15	75
1920	0	1	0	1	26	14	5	6	51	29	28	11	1	69	34	28	19	81	36	10	3	49
1921	1	1	0	2	36	7	5	2	50	25	19	6	1	51	51	24	14	89	24	10	7	41
1922	2	1	3	6	33	8	6	2	49	38	23	10	7	78	38	21	10	69	31	15	6	52
1923	0	0	0	0	26	13	3	4	46	21	17	6	2	46	37	29	4	70	22	9	1	32
1924	0	3	1	4	25	10	11	2	48	28	33	9	10	80	33	46	19	98	41	32	27	100
1925	3	1	2	6	14	6	1	2	22	26	21	6	0	53	25	35	7	67	19	5	1	25
1926	2	6	1	9	24	10	11	2	47	28	37	11	3	79	34	33	18	85	28	13	5	46
1927	1	0	1	2	21	9	10	0	40	19	16	8	2	45	33	22	12	67	22	10	5	37
1928	1	1	2	4	28	14	10	1	53	26	20	5	1	52	43	29	11	83	43	22	8	73

TABLE 6a.—*Number of days with low relative humidity, within the limits indicated, for each season.* (*May to September, inclusive*)

Year	Medford, Oreg.					Bend, Oreg.				Lakeview, Oreg.				
	30-26	25-20	19-15	14	Total	25-20	19-15	14	Total	25-20	19-15	14-11	10	Total
1925	29	38	12	2	81									
1926	34	31	3	0	68	41						35	27	102
1927	25	31	8	0	64	32	18	3	53	21	35	14	11	81
1928	36	34	17	2	89	32	46	15	93	28	30	27	23	108

TABLE 7.—*Average frequency of days with low relative humidity, within the limits indicated, for July and August, seasons of 1925 to 1928, inclusive, by State subdivisions of cooperating stations reporting in Oregon*

State subdividion	Number of stations	Average elevation (in feet)	Average number of days per season with relative humidity (per cent)						
			40 or lower	35 or lower	30 or lower	25 or lower	20 or lower	15 or lower	10 or lower
Coast	5	74	0.2	0	0	0	0	0	0
Coast Range	6	1,410	11	7	3	1	0.1	0	0
Willamette Valley	7	312	25	17	8	3	0.5	0	0
Cascade Range, west slope	16	3,326	31	23	16	8	4	1	0.3
Southwest portion	10	1,682	43	36	28	17	7	1.6	0.1
Cascade Range, east slope	9	3,849	48	42	35	25	14	5	0.5
Northeast portion (Blue Mountains)	13	4,467	46	41	34	26	16	6	1
Southcentral portion	9	4,841	53	46	42	36	27	15	5

Coast elevations range from 10 to 200 feet.
Coast Range elevations range from 300 to 3,437 feet.
Willamette Valley elevations range from 57 to 800 feet.
Cascade Range, west slope, elevations range from 100 to 9,493 feet.
Southwest portion elevations range from 200 to 5,310 feet.
Cascade Range, east slope, elevations range from 1,500 to 6,425 feet.
Northeast portion (Blue Mountains), elevations range from 1,018 to 9,640 feet.
Southcentral portion elevations range from 3,950 to 6,000 feet.

CLOUD HEIGHT ACCORDING TO DIRECTION OF MOTION

By ARTHUR F. PIPPO

[Weather Bureau, Madison, Wis.]

In recognition of the need of more reliable determinations of "ceiling" by eye observation, a summary of cloud heights at Madison, Wis., Washington, D. C., and Blue Hill near Boston, Mass., was made. It includes five common types, which occur within the "flying level," and for which data are available. Mean heights of clouds above the surface were calculated for the different directions of their motion, the directions being combined into approximate quadrants, first quadrant, ESE. to NE., second quadrant, NNE. to NW., etc.

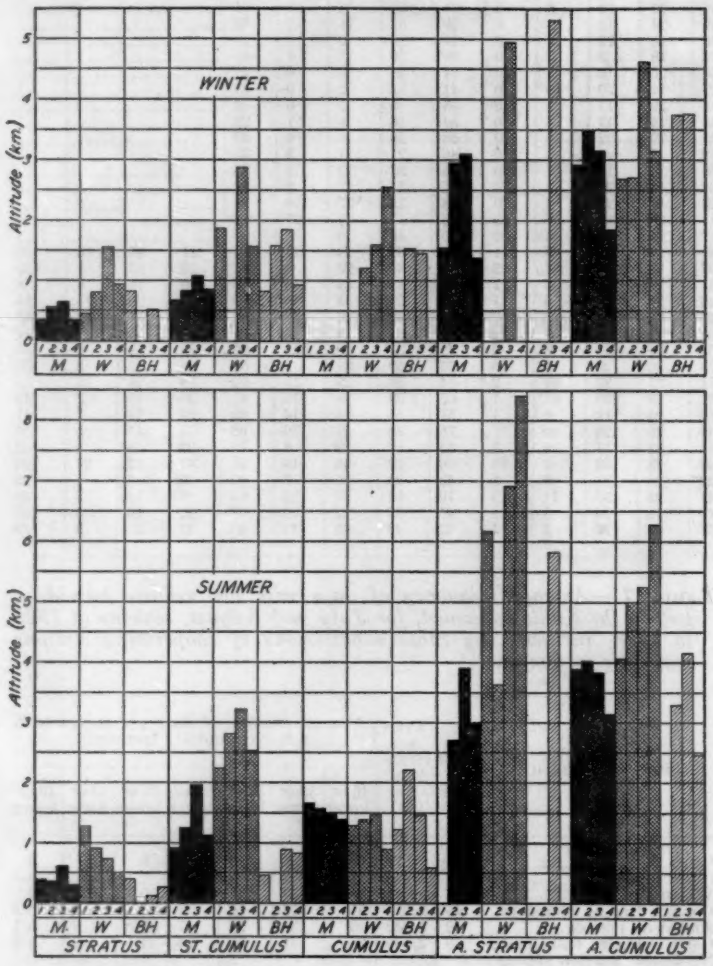


FIGURE 1.—Cloud heights at Madison (M), Washington (W), and Blue Hill (BH)

It is a well-established fact that whatever condition tends to increase the humidity of the air lowers the height of the condensation level. This is apparent from the position (well to the eastward of the center of the low) of the region of maximum condensation in our extra-tropical cyclones. Examination of the accompanying figure which has been prepared from the summarized figures in Table 1 reveals conclusively the necessity of observing the direction of motion in estimating cloud base heights by eye observation.

The data for Madison (307 meters above sea level) consist of 1,245 observations by means of pilot balloons during the period May, 1919, to February, 1927. The Washington (36 meters above sea level) data (1) include a total of 836 determinations by theodolite triangulation during the international cloud year, 1896–97, while the record for Blue Hill (202 meters above sea level) data (2) contains only 290 observations of the types considered during the same year. The averages for Washington and Blue Hill are for 6-month periods, while the Madison data has been divided into 3-month seasons.

From the figure it is evident that clouds are highest when moving from westerly points and lowest from points east. The stratus type, for instance, is twice as high from west as from the east. An obvious inconsistency appears in the Washington data for stratus, it averaging over 1 kilometer in two cases, whereas the international committee on clouds in 1905 defined the limits of stratus base at that figure. In the case of strato-cumulus, the differences in height from the different quarters is essentially the same at the three places, but the average height for the type varies widely. On the other hand, convective cumulus and alto-cumulus occur at a fairly common average height at the three places, but the height-direction characteristics show little agreement.

As with stratus and strato-cumulus, so also alto-stratus shows a large difference in the average height at Madison and Washington. This apparent divergence of elevation of stratiform clouds, and the close agreement of convective levels, makes for an open problem. It is evident, however, that observation of cloud motion is of considerable value in estimating "ceiling" where no instruments are available, and with the ever-increasing records from the numerous aerological stations sufficient data should not be lacking to make interesting a thorough comparative investigation of this phase of cloud study.

CITATIONS

(1) Bigelow, F. H. Report on the International Cloud Observations, Report of the Chief of the Weather Bureau, 1898–99, vol. 2, p. 334.

(2) Clayton, H. H. Measurement of Cloud Heights, Velocities, and Directions. Annals of Harvard College Obs., vol. 42, p. 249.

TABLE 1.—*Average altitude of clouds above the surface, according to season and direction of motion, at Madison, Wis., Washington, D. C., and Blue Hill near Boston, Mass.*

		Direction from—	Stratus	Strato-cumulus	Cumulus	Alto-stratus	Alto-cumulus		Stratus	Strato-cumulus	Cumulus	Alto-stratus	Alto-cumulus
Madison	Winter	ESE. to NE.	328	659	X	1,544	2,886	Summer	378	901	1,650	X	3,869
		NNE. to NW.	537	804	X	2,921	3,471		363	1,250	1,567	2,700	4,017
		WNW. to SW.	612	1,069	X	3,066	3,124		620	1,974	1,483	3,896	3,812
		SSW. to SE.	340	823	X	1,362	1,854		293	1,128	1,379	3,018	3,130
	Spring	ESE. to NE.	344	896	1,350	2,768	X	Autumn	356	825	1,330	X	2,403
		NNE to NW.	547	951	1,411	2,632	3,149		434	864	911	3,680	3,007
		WNW. to SW.	439	1,276	1,430	3,352	3,008		821	1,419	1,551	3,083	3,333
		SSW. to SE.	461	1,144	1,078	2,237	3,068		449	1,162	927	3,912	4,896
Washington	Winter	ESE. to NE.	449	1,856	X	X	2,664	Summer	1,267	2,249	1,289	6,148	4,060
		NNE. to NW.	806	X	1,201	X	2,682		899	2,840	1,383	3,648	4,988
		WNW. to SW.	1,562	2,835	1,581	4,940	4,639		732	3,231	1,492	6,935	5,234
		SSW. to SE.	922	1,550	2,549	X	3,146		747	2,539	904	8,410	6,272
Blue Hill	do	ESE. to NE.	824	802	X	X	X	do	382	452	1,213	X	X
		NNE. to NW.	X	1,580	1,516	X	3,753		X	995	2,225	X	3,295
		WNW. to SW.	510	1,813	1,452	5,276	3,777		127	894	1,447	5,820	4,146
		SSW. to SE.	X	917	X	X	X		270	832	590	X	2,495

(To face p. 155)

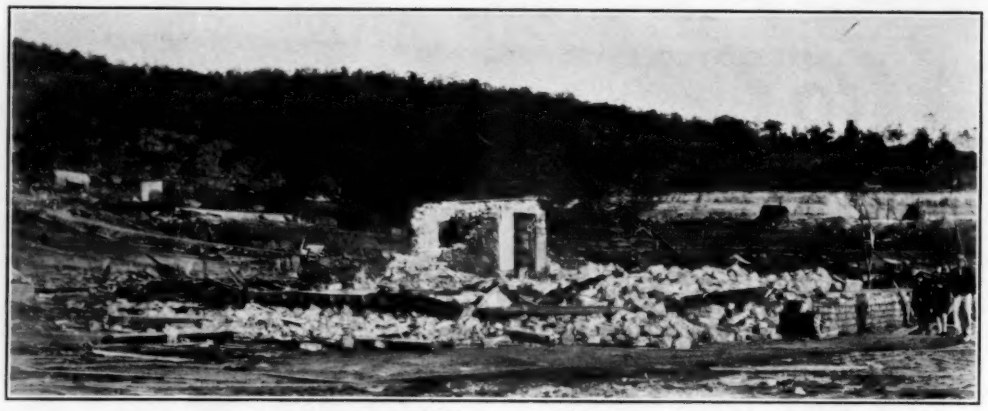
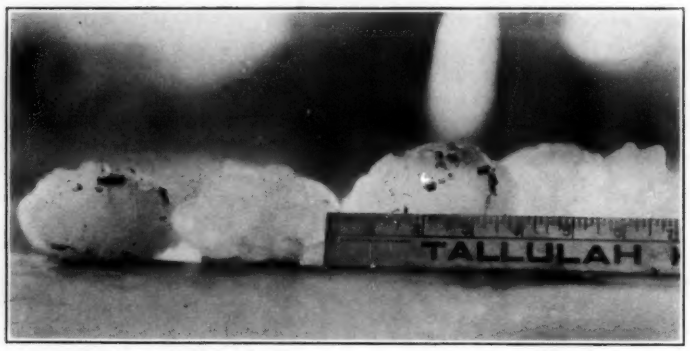
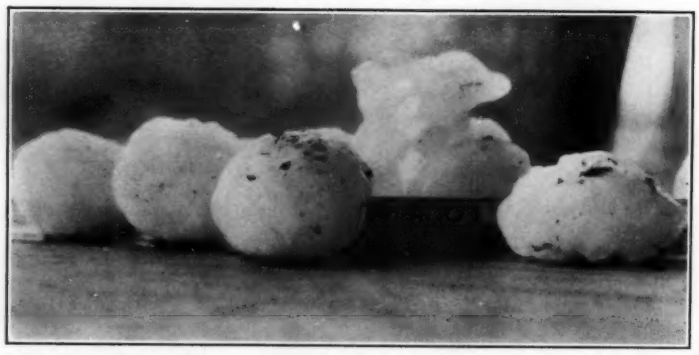


FIGURE 1.—Ruins of the Izard County Bank at Guion, one side and top of vault torn off. Building made of concrete blocks. Photo by Carl Olsson





Hailstones at Tallulah, La., April 21, 1929

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TORNADOES IN ARKANSAS, APRIL, 1929

H. S. COLE, Meteorologist, Little Rock, Ark.

April 10, 1929, may be called a tornado day in Arkansas. The records show but three days on which more places were visited by tornadoes than on that date. Thirty-four places were visited by tornadoes on June 5, 1915, 28 on November 25, 1926, and 25 on May 9, 1927. Eight tornadoes were reported in the northeastern portion of Arkansas during the afternoon and the early portion of the night of April 10, damage being reported at 17 different localities by these storms. The first occurred 3 miles west of Calico Rock, Izard County, at about 3 p. m., the last at Parkin, Cross County, at 8.30 p. m.

The tornadoes of April 10 occurred over an area in the shape of a triangle, the northern edge extending 100 miles eastward from Calico Rock to northern Mississippi County, the eastern edge from northern Mississippi County southward 60 miles to Cross County. The disturbance that caused the tornadoes moved eastward across the area, and, according to reports received at this office, the resulting tornadoes caused the death of 56 persons, injured 213 persons seriously, and destroyed property values at $795,000. It is thought the number of dead is about correct, but the number of injured and the property losses were much greater than reported.

The first tornado occurred 3 miles west of Calico Rock about 3 p. m. It came from the southwest, causing considerable destruction of timber, but fortunately only a few small buildings were in the path and with the exception of the timber destroyed little damage occurred. It was a small tornado and disappeared after moving a short distance.

A small tornado occurred at Mount Pleasant at 4.30 p. m., doing but slight damage and traveling but a short distance. An eye witness states that the storm was coming from the west but was deflected toward the northeast by a mountain west of the town.

A second tornado visited Mount Pleasant about 30 minutes later. It originated at Harpel a little before 5 p. m. and moved rapidly eastward, striking Guion at 5 p. m. and Mount Pleasant a few minutes later. It covered a path 1,000 feet wide and 18 miles long. It evidently moved very rapidly as it was reported at the three towns at the same time. It was only about 4 minutes from the time it was first seen at Guion until it was gone. Two persons were killed at Harpel, 5 at Guion, and 45 were injured at Guion and 3 at Mount Pleasant. Property valued at $166,000 was destroyed. Only 3 of the 150 buildings in Guion were left standing. The Izard County Bank was built of concrete blocks, which were strewn in every direction, the vault being torn open as shown in Figure 1. The only shelter for the wounded and the women and children was the three remaining houses and the tunnels to the mines.

Two tornadoes are supposed to have formed near Almond, in Cleburne County, and to have moved slightly north of east. Persons in Batesville who were watching the tornadoes thought they were one tornado until the storms were near White River, where they thought one tornado split off from the other and moved toward the northeast, the other moving on eastward to Moorefield, Independence County, after which it dissipated. The one that changed to a northeasterly course was reported 4 miles west of Charlotte, in the same county, at about 5 p. m., 4 miles north of Cord at 5 p. m. (probably later), crossing Black River north of Kenyon, in Jackson County, following an east-west section line 3 miles north of Swifton, Jackson County, at 6.30 p. m., and in the Lorado community, Green County, at 7.45 p. m. It is thought that the tornado that formed at Almond was the same one that caused so much destruction near Swifton and in the Lorado community. If it were, it traveled about 65 miles. It was a small tornado at first, skipping along rapidly over a narrow course, but later the path became wider and the storm moved slowly. Near Swifton it was an immense tornado, with extremely high wind velocities, scarcely leaving a thing standing in a path over half a mile wide. High wind velocities seem to have accompanied the storm from the time if formed until it disappeared.

No serious damage was done by either of these storms until Moorefield was reached. Here 10 persons were injured and a property loss of $20,000 was sustained. The other tornado did but little damage until it reached a thickly settled community along the highway running east and west 3 miles north of Swifton, where 23 person were killed, 32 were seriously injured, and property valued at $155,000 was destroyed. The storm soon changed its course again to the northeast into the Lorado community, where 8 persons were killed, 30 were injured, and property losses estimated at $150,000 were sustained. In the entire course of this storm 31 persons were killed, 72 were injured seriously enough to receive medical attention, and property valued at $327,000 was destroyed. The tornado was accompanied and followed by rain, hail, and cold winds, causing intense suffering by the injured and homeless. Rescue work was very difficult, owing to the darkness and the storm, some of the dead and injured not being found until the next morning. The usual number of things occurred that can not be explained, the most startling being the fact that the town of Guion, about 296 inhabitants according to the census of 1910, was literally blown away and only 5 persons killed. Houses were blown to pieces and the floor and a bed left with the occupants uninjured, etc. One witness states that when the tornado struck a house it went all to pieces in an instant as though it exploded. There may have been some explosions, due to decreased pressure on the outside, but in most cases it was probably the centrifugal force of the mass of air and débris and the upward currents, carrying the pieces of the houses outward and upward. The heavier pieces would force themselves out farther from the center of the whirling mass.

A small tornado occurred at Diaz, Jackson County, at 6:20 p. m. No one was killed or injured, but the property loss was $11,000.

Another small tornado occurred at Monette, Craighead County, at 8 p. m., in which no one was killed or injured, but the property damage was estimated at $40,000.

The eighth tornado of the day originated southwest of Wynne, Cross County, at about 8 p. m. or a little later and moved slightly north of east. The first damage was at Smiths Chapel (no post office), a few miles southwest of Wynne. One person was killed, 37 injured, and a property loss of $50,000 was reported. The tornado then moved eastward to a community just west of Princedale, same county, where 4 persons were killed and the property loss was estimated at $5,000. At Princedale 11 persons were killed, 50 were injured, and property valued at $75,000 was destroyed. The tornado

then continued its course eastward 4 or 5 miles to Parkin, where 1 person was killed, 4 injured, and a property loss of $70,000 was sustained.

High pressure prevailed over the Canadian Provinces and west of the Rockies, low pressure elsewhere on the morning of the 10th, the principal low center being over eastern Kansas with a reading of 29.46 at Wichita. At the time of the evening observation the low had moved southeastward to north-central Arkansas, the lowest reading being 29.58 at Little Rock. By the morning of the 10th it had moved almost due northward to eastern Iowa. The low was nearly round or slightly elliptical, the longer axis being nearly north and south most of the time.

We would not think of this kind of a map when speaking of a tornado map. We usually think of tornadoes in connection with an elongated low, the longer axis extending northeast and southwest, or a trough of low pressure with low centers over the Lakes and Texas.

The tornadoes of the 10th occurred from about 50 miles to 150 miles from the center of the low. The ones that occurred first were moving from the southwest, those that occurred a little later were moving from slightly south of west or west, those still later were from the southwest again, the one that continued from 4 p. m. to 7:45 p. m. changing its course first coming from the west, then from the southwest, from the west again, and later from the southwest again. As nearly as we can determine the storms followed the isobars most of the time. It is difficult to show why the tornado at Calico Rock, the first one at Mount Pleasant, and the first one at Moorefield were from the southwest, and the ones so soon after were from nearly west, especially the second storm at Mount Pleasant and the one at Moorefield. The first and second storms at Moorefield were in sight at the same time. With the exception of the Lorado community these storms were moving almost directly eastward when they were causing great destruction of life and property.

There seem to have been three fronts or disturbances along which the tornadoes formed. The first reached Calico Rock at 3 p. m. and Mount Pleasant at 4.30 p. m. The second passed Almond at 4 p. m., Moorefield at 4:20 p. m., Charlotte at 5 p. m., Swifton at 6.30 p. m., Lorado at 7.45 p. m., Monette at 8 p. m., and Parkin at 8.30 p. m. The third passed Harpel, Guion, and Mount Pleasant in quick succession at about 5 p. m. The storms that formed along the first moved from the southwest, those along the second from the west until after 6.30 p. m., then from the southwest most of the time, the one along the third from the west.

A small tornado occurred at Subiaco, Logan County, on April 14, destroying a few small buildings, but not doing any serious damage.

On April 20 tornadoes occurred at Buckner, Lafayette County; Clinton, Van Buren County; London, Pope County, and Oil City (4½ miles south and 3 miles east of Batesville). Three persons were injured at Oil City, the property damage at all places on the 14th and 20th being about $34,000.

A tornado occurred on April 21 at Tillar, Drew county, causing the death of 12 persons, the serious injury of 2 others, and property damage estimated at $1,000. This was a small storm but struck two houses, causing the deaths mentioned.

The total number of places visited by tornadoes in Arkansas during April was 22, one of these places being visited by two tornadoes in about half an hour. Sixty-eight persons were killed in these storms, 218 injured, and property losses amounting to $830,000.

The following table, gives considerable detailed information that is not given in the text:

Tornadoes in Arkansas, April, 1929

Location	Date, April	Hour	Width path	Length path	Direction from which storm came	Number killed	Number injured	Damage
		p. m.	*Feet*	*Miles*				
Almond	10	4:00	Narrow.	65	WSW.	0	0	$2,000
Calico Rock (near)	10	3:00	650	1	SW.	0	0	Slight.
Charlotte (4 miles west)	10	5:00	600	65	SW.	0	0	Slight.
Cord (3 miles north)	10	5:00				0	0	1,000
Diaz	10	6:20	900	2	SW.	0	2	11,000
Guion	10	5:00	1,200	18	W.	5	45	200,000
Harpel [1]	10	4:50		18	W.	2	0	1,000
Lorado (southwest Green County, no post office).	10	7:45	3,500	65	SW.	8	30	150,000
Monette	10	8:00	650	2	SW.	0	0	40,000
Moorefield	10	4:20	500	65	WSW.	0	10	20,000
Mount Pleasant	10	4:30	Narrow.	Short.	SW.	0	0	Slight.
Do	10	[2] 5:00	1,000	18	W.	0	3	15,000
Parkin	10	8:30	300	16	WSW.	1	4	70,000
Princedale (west of)	10	[3] 8:30	Narrow.	16	WSW.	4		5,000
Princedale	10	8:30	300	16	WSW.	11	50	75,000
Smith's Chapel (no post office, southwest of Wynne).	10	[3] 8:30		16	WSW.	2	37	50,000
Swifton (3 miles north of)	10	6:30	2,640	65	W.	23	32	155,000
Subiaco	14	(4)	Narrow.	Short.	SW.	0	0	Slight.
Buckner	20	3:30		Short.	SW.	0	0	1,000
Clinton	20	7:25	600	Short.	SW.	0		11,000
London	20	6:30	300	Short.	SW.	0	0	9,000
Oil City [5]	20	8:45	225	Short.	NW.	0	3	13,000
Tillar	21	2:45	Narrow.	5	W.	12	2	1,000

[1] Southwest Green County.
[2] After 5 p. m.
[3] Before 8.30 p. m.
[4] Afternoon.
[5] 4 miles south, 3 miles west, of Batesville.

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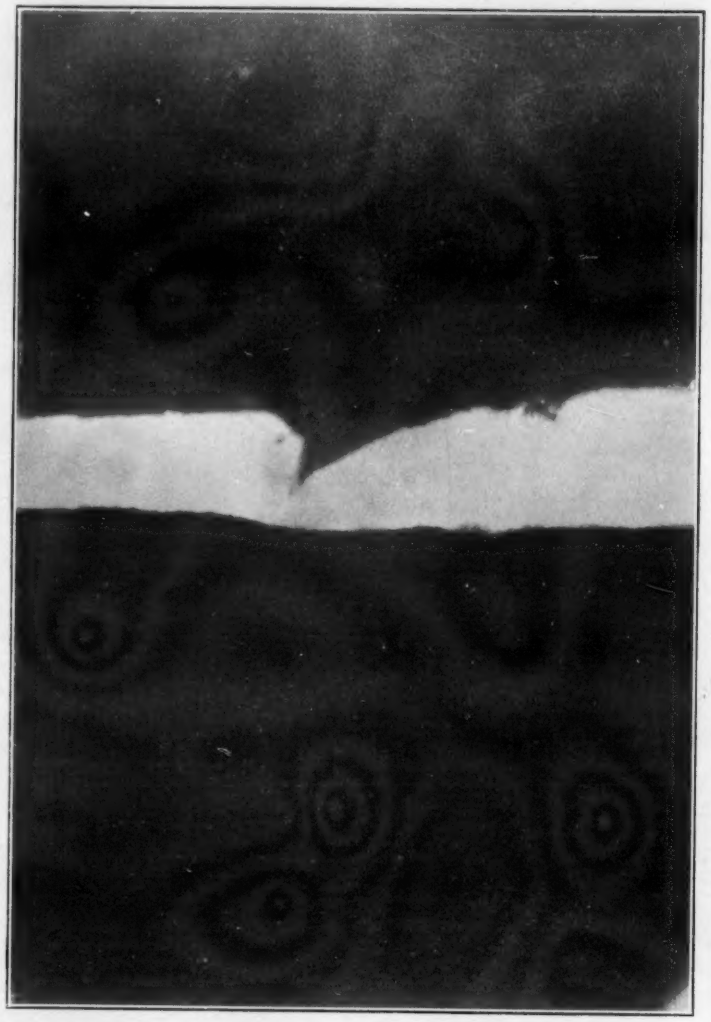
(To face p 157)



Tornado at River Falls, Wis., 5.50 p. m., April 5, 1929. Bartosh Photo

Tornado at River Falls, Wis., No. 2, 5.52 p. m., April 5, 1929. Bartosh Photo

Tornado at River Falls, Wis., No. 3, made at 5.53 p. m., April 5, 1929. Bartosh Photo

TORNADOES IN WISCONSIN, APRIL, 1929

By W. P. STEWART
[Weather Bureau Office, Milwaukee, Wis.]
(Condensed by the Editor)

In this month three tornadoes were observed under rather unusual meteorological conditions. Two occurred late in the afternoon of the 5th, one of which traversed the State of Wisconsin from Pierce County to Iron County, a distance of 187 miles, at a speed of 68 miles an hour.

This tornado occurred in a belt of thunder and wind storms about 250 miles in width. Pressure in this belt ranged from 29.50 to 29.70 inches from a central low pressure of 28.92 inches at Moorehead, Minn. The morning temperature was quite a bit below 70° at the morning observation. The path of great destruction varied in width from 100 to 1,200 feet, but there was more or less damage over a width of 10 to 20 miles from the path of great destruction; evidently the destruction outside of the central path was due to the storm winds of the cyclone which, as above noted, had a central pressure below 29 inches.

The third tornado entered Wisconsin from Iowa in the neighborhood of Dubuque. It occurred on the 6th and was associated with a cyclonic storm centered over northeast Colorado. In this case, also, there was a narrow belt of thunderstorms that stretched from eastern Kansas to Lake Michigan. The details of these tornadoes are given in the table on pages 165–166.

Three photographs of the River Falls tornado cloud were made by Mr. Claire Bartosh, who lives on a farm near River Falls. From the prints supplied through Mr. C. G. Stratton, cooperative observer at that station, the reproductions of Figure 1 were made. The first photograph was made at 5:50 p. m., April 5, 1929, and the remaining two within the space of 5 minutes thereafter. The lack of detail in the foreground is due to the fact that it is plowed ground. Between the plowed ground and the tornado cloud is the river valley.

The original prints are 2 by 3 inches and they have been slightly enlarged in the reproduction. The interesting feature in them is the change in the funnel cloud that took place in 5 minutes.

HAIL APRIL 21, 1929, IN KENTUCKY, ILLINOIS AND LOUISIANA

By J. L. KENDALL, W. E. BARRON, and R. A. DYKE, of the Weather Bureau stations at Louisville, Cairo, and New Orleans, respectively

HAIL IN LOUISVILLE, KENTUCKY

A hailstorm of unusual character and causing heavy damage visited the locality immediately northwest of this station from 2:30 to 2:45 p. m. on April 21, 1929. The center of the heaviest hail was over New Albany, Ind., where stones ranging from 2 to 3 inches in diameter fell with considerable frequency. A large quantity of smaller hail, from the size of a pea to an inch in diameter, also occurred. Near the end of the storm the ground was nearly covered with ice.

The area reached by the very large stones extended east to Jeffersonville, Ind., where the writer measured stones that were 2 to 2¼ inches in diameter; and also included the northwest quarter of Louisville. The frequency of the large stones diminished as the distance from eastern New Albany increased. At Jeffersonville they fell on the average about 1 to 2 feet apart, sometimes 3 feet.

The area reached by hail of smaller size extended for about 10 miles north of Louisville, and for about 20 miles in a southerly direction; but no hail of the size given above has been reported in these outside districts. In general the largest hail in those sections was about 1 inch in diameter. Hail also occurred at many other places in the State of Kentucky and in southern Indiana. From reports received it seems that hail was exceptionally widespread in this section on that day.

There were two kinds of large hailstones, apparently formed by different methods. One was of the usual type, in which concentric layers of ice and snow make up the stone and the appearance of the mass is white. These were as large as an inch in diameter at my place in Jeffersonville, Ind. The other stones were apparently made up of a mass of smaller stones frozen together, and were nearly all ice. The rim of these stones was jagged, where smaller stones had frozen to the central mass and projected. Across the central mass of ice, without including these projections, they measured 2 to 2¼ inches at Jeffersonville. According to reports, they were somewhat larger at New Albany.

These stones were flat in shape, with the shorter diameter about 1 inch or slightly more. Around the rim of the stone the radial lines of the smaller stones could be seen embedded in the mass of ice. The shape of the smaller stones, of which the mass appeared to be built up, could be plainly seen in the outer one-third of the diameter of the mass. The lines of these stones radiated outward from the center of the mass, not always regularly but comparatively so. From these lines and the stones frozen on the rim and projecting, the mass seemed to be made up of stones about twice as long as they were thick and somewhat cylindrical in shape but with flattened sides. These were the outstanding features of the stones, but it is not to be understood that they were regular in shape for they exhibited marked irregularities in the way of protuberances on the flat sides and rim. The small stones that made up the mass contained much less snow than the usual hailstone. They were almost solid, clear ice. This fact accounts in part for the enormous damage caused by these stones, for they were almost as heavy as a piece of solid ice of the same size.

The heaviest damage was to greenhouses in New Albany and between New Albany and Jeffersonville. This loss alone was estimated at $60,000 to $70,000. Auto tops were penetrated, hoods and fenders were dented, holes were cut in metal roofs, and shingle roofs were badly damaged. Hundreds of windows were broken. The entire damage in New Albany, Jeffersonville, and the district lying between, was placed at about $100,000. No estimate could be obtained of the damage in the northwest part of Louisville, but it is believed that $10,000 will cover most of it. The damage in that district was mostly to automobiles, windows, and occasional roofs.—*J. L. K.*

HAIL IN LOWER OHIO VALLEY

A hailstorm of wide extent occurred on Sunday afternoon, April 21, 1929, in connection with a series of depressions that at morning observation covered the Ohio and lower Mississippi Valleys with the lowest pressure at Cairo, Ill., 29.69 inches, reduced to sea level. The hail area in this vicinity covered most of Alexander and Pulaski Counties and parts of Union and Johnson Counties in Illinois, parts of Mississippi and Scott Counties of Missouri, and most of Ballard and McCracken Counties, with parts of Carlisle and Graves Counties in Kentucky. There was no hail at Cairo, the nearest being about 5 miles north and 5 miles east and southeast of station.

Hailstones over the area varied in size from one-fourth inch to 2¼ inches in diameter, over much of the area more than one-half inch. The area of heavy hail (1 inch or more in diameter) was apparently about 4 miles wide and 30 miles long, stretching from near Olive Branch and Miller City eastward across Alexander and Pulaski Counties, thence southeastward across Ballard County, Ky., diagonally to Lovelaceville. Hailstones that fell at Roth Station, 2 miles west of Cache, Alexander County, Ill., brought to Cairo, in a glass jar, were disk shaped and measured 2 inches in diameter 2 hours after falling. The time when the storm broke ranged from 2:30 p. m. at the western end of the path to 4:30 p. m. at the eastern end. At some places the fall is reported to have lasted 30 minutes.

Damage to property was confined mostly to composition roofs, automobile tops, and hotbeds; very little to windows, as the wind was not strong; approximate loss, $30,000; $20,000 in Illinois and $10,000 in Kentucky. Damages to truck crops, berries, and tree fruits can not be determined accurately, but will probably equal the amounts of property damage in the two States. No appreciable damage was reported in the Missouri area.—*W. E. B.*

HAIL IN NORTHEAST LOUISIANA

During the afternoon of April 21, 1929, the eastward movement of a trough of low pressure was attended by thundershowers in northern Louisiana and violent convectional action accompanied the shifting of the wind from southerly to westerly, a tornado occurring in one locality and a remarkable fall of hail in another.

At about 3:45 p. m., a tornado, moving eastward or slightly south of east, over a path 18 to 50 yards wide and 8 miles long, passed near Oak Ridge, in Morehouse Parish. A distinct funnel cloud, described as "very small at bottom and not spreading out until very high," was observed. The tornado demolished a few houses about 2 miles south and southwest of Oak Ridge, killing two persons and severely bruising a few others. The property damage is estimated at $7,550.

As the squall line moved farther eastward a hailstorm occurred in the vicinity of Tallulah, about 38 miles southeast of Oak Ridge, between 4:30 and 5 p. m. The hailstones, falling over an area about 20 miles wide (length not given), were scattering but remarkably large. Mr. G. L. Smith, of Tallulah, reports:

"Authentic reports have been received of a few stones measuring 4 by 4 by 6 inches. A few very large pieces of ice fell before the main storm began. The falling of large stones lasted less than 10 minutes and was followed by a little rain for about 30 minutes. Most of the stones were round and very compact. They remained on the ground for a good while after the storm had passed. The small amount of damage was no doubt due to the fact that the hailstones were not nearly so numerous as in the usual hailstorm. A little damage occurred to roofs, car tops, and glass structures. The accompanying photograph (see plate facing page 155) illustrates the size of the hailstones."—*R. A. D.*

DISCUSSION

On the morning of the 21st the pressure distribution was about as follows: An anticyclone of considerable intensity and geographic extent was centered along the west shore of Hudson Bay, the true center being a small distance inland from the mouth of Nelson River. A trough of low pressure stretched from Cape Cod to eastern Kansas and a second trough oriented northwest/southeast covered the region between southern Alberta and northern Wyoming. These two troughs were in the proper position to give showers and thunderstorms in the same 24 hours from the Atlantic to the Pacific. A single thunderstorm was occurring on the morning of the 21st in Massachusetts, thence westward there was a break in their continuity, none occurring until the Ohio Valley was reached. Here they were quite general and the area covered by them reached to eastern Kansas on the west. As the day wore on they became much more general and of greater severity in spots. In the Ohio Valley a house was blown down and the inmates suffered injury. Hail was also of general occurrence along the line of the trough from the Ohio Valley to the Atlantic.—Ed.

SQUALLS WITH RISING BAROMETER AT ROSEBURG, OREGON

By EDGAR H. FLETCHER

[Weather Bureau Office, Roseburg, Oreg., April 15, 1929]

It frequently has been observed here in the late winter and early spring that with rising barometer and clearing weather the advancing cold air mass with the resultant steep vertical temperature gradient, causes a succession of light squalls from the west or northwest accompanied by precipitation in the form of showers (rain or snow), and usually by light hail, but without thunder and lightning. Thus there is during the greater part of the day under such conditions, a frequent alternation of sunshine and storm, with decidedly cool weather prevailing.

The small ice pellets accompanying these extremely local showers should be classified as hail, rather than sleet; for an inversion of temperature is necessary for the formation of true sleet, which usually occurs with the approach of a warm front during the colder season of the year.

These intermittent showers, occurring every hour or two during the warmer part of the day, are of short duration, usually lasting less than 30 minutes. A steep vertical temperature gradient no doubt exists at the time, and it is probable that the convectional activity is confined to a comparatively shallow layer of the air. If the maximum temperature for the day is below 50°, it is not unusual to obesrve rain, hail, snow, and probably sleet within an interval of 5 or 10 minutes, but the precipitation is always light. Often the fine ice pellets resemble sleet so closely that they are recorded as such.

It is evident that the Coast Range plays an important part in the formation of these local disturbances, since the air is forced upward to about the 2,000-foot level in

passing over the mountains. The first indication of rather strong convectional activity is seen over the Coast Range in the form of cumulus and cumulo-nimbus clouds which are associated later with a light local storm that eventually reaches the vicinity of Roseburg, 10 miles east of the main range. The whole region in this vicinity between the Coast Range and the Cascades consists of broken hills of considerable elevation and narrow, irregular valleys along the winding water courses.

During the passage of some of these storms, visibility and ceiling are reduced to a minimum, and especially if snow predominates, as it often does on the mountains and higher hills, if the day is unusually cool. It occasionally happens that an airplane is forced to land in this vicinity on account of one or more of these local "snow showers" prevailing in or near this region; but usually the chief menace from local snow storms occurs in the transverse ranges of mountains and hills marking the northern and southern limits of the Umpqua basin in which Roseburg is situated.

Weak squall conditions are likely to prevail for a day or more at a time of slowly rising barometer, or the short transition period of upward pressure tendency between the passages of successive cyclonic areas. In fact a large percentage of the rainfall during the spring season occurs under such pressure conditions, very little rain occurring while the barometer is falling, except for slight subsequent falls, or when the center of the storm passes near the station. However, there usually is a period of maximum rainfall that occurs during the first part of the pressure rise, before the squall stage is reached. The abnormally cold and dry season that has prevailed this spring, 1929, seemed to be unusually favorable for squall formation.

NOTES, ABSTRACTS, AND REVIEWS

The second conference on cycles.[1]—The first conference was held in December, 1922, and was reported on in Geographical Review, Special Supplement, vol. 13, 1923, pp. 657–676. The purpose of the second conference was the discussion of new material accumulated since the first conference.

A reading of the abstract of the work of the second conference leaves the impression that beyond methods of refinement in observational methods, the status of the problem of cycles, whether in solar radiation, tree rings, clay varves, or whatnot, has not risen above the position that it has occupied for the last quarter of a century. The suggestion was made that a point had been reached where some or all of the observations should be duplicated in the Southern Hemisphere.

The meeting was held in Washington, D. C., on December 15, 1928, under the direction of President Merriam, of the Carnegie Institution of Washington, with Dr. D. T. McDougal, of the institution's division of plant biology, in the chair; present also 35 other scientists representing a number of the physical sciences.

High lake levels.—Meteorologist J. H. Spencer, in charge of the Weather Bureau station at Buffalo, N. Y., sends the editor an account of the severe wind storm that prevailed on April 1, 1929, at that station. The speed of the wind on this occasion reached at 3:10 p. m. a velocity of 78 miles per hour, for a 5-minute period, and this is the greatest velocity of record for any month. Naturally, considerable damage was caused by the high winds; trees 1 to 2 feet in diameter were blown down, frail houses and garages were unroofed, and in some cases overturned. Several steamers in the harbor were torn loose from their moorings and the water in the harbor rose 7.8 feet above its normal level. Mr. Spencer also furnished a copy of the drawing made by the United States engineers at Buffalo from which Figure 1 is reproduced.

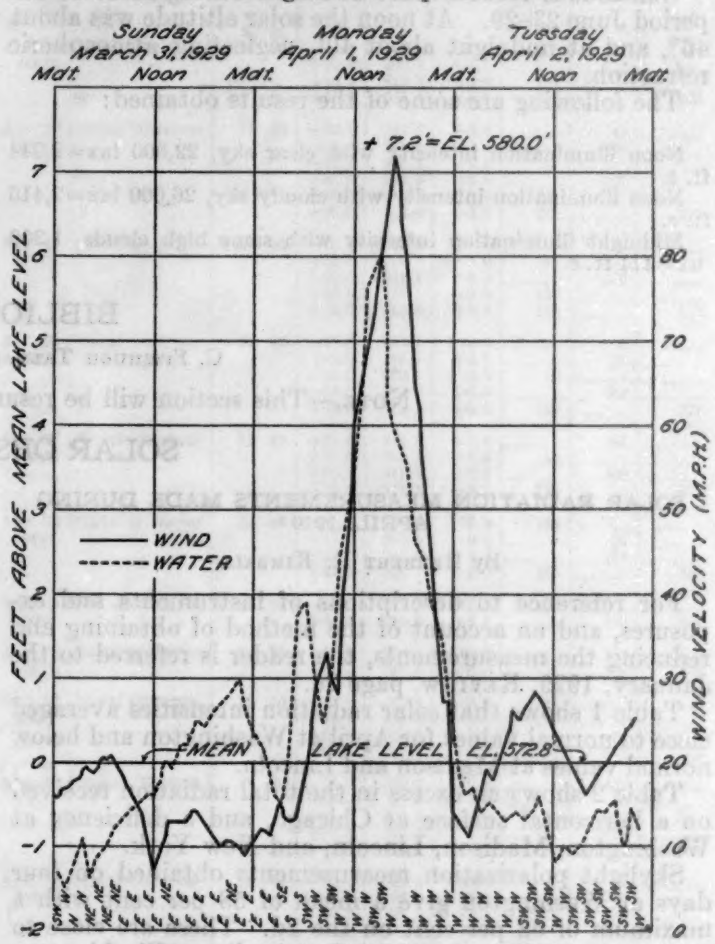


FIGURE 1.—Winds and Lake levels, April 1, 1929

The heaping up of the water of Lake Erie in Buffalo harbor due to strong westerly winds is a well-known feature of that harbor. The figure shows the rapid rise of the water almost concurrently with the increase in wind velocity; it also shows a lowering of the water in the early part of the day due to the prevalence of east winds.

On April 12, 1929, the New York Times printed dispatches from a number of places in the lake region all but one of which reported dangerously high water in the Lakes. On looking up the weather chart for the day in question it was found that east to northeast winds had prevailed for more than 24 hours. Inasmuch as the places reporting high water were on the western shore of Lake Michigan the conclusion is unavoidable that the high water was the result of wind action.—*A. J. H.*

Kalitin on illuminiation by diffused light during the solar eclipse, June 29, 1927.[1]—Malmberget, Sweden, is at latitude 67° 20′ N., longitude 20° 54′ E. Continuous records of the intensity of the illumination by diffused light were obtained by means of a potassium photocell covered with a horizontally adjusted milk-white glass with a feeble yellow light screen, selected so as to render the spectral sensitiveness of the photocell approximately

[1] Geographical Review XIX: 296-306, April, 1929.

[1] Geografiska Annaler, 1928. H. 3.

that of the naked eye. The photocell was completely shaded from direct sunlight by a small clock-driven disk. The recording device consisted of a galvanometer that registered every two minutes. Comparisons of galvanometer records and photometer readings permitted the former to be reduced to light units.

Continuous records were obtained during most of the period June 23–29. At noon the solar altitude was about 46°, and at midnight about 40′, neglecting atmospheric refraction.

The following are some of the results obtained:

Noon illumination intensity with clear sky, 22,000 lux=2,044 ft. c.

Noon illumination intensity with cloudy sky, 26,000 lux=2,415 ft. c.

Midnight illumination intensity with some high clouds, 1,200 ux=111 ft. c.

The duration of totality of the eclipse was 40 seconds. During this time, with 8 A. Cu. clouds present, photometric measurements gave for the horizontal illumination intensity 6.8 lux=0.6 ft. candles.

These are somewhat higher values than were obtained by me at Washington,[3] namely, with the sun 46° above the horizon and a clear sky, 1,450 ft. c. and with the sun at the same altitude but with a cloudy sky, 1,600 ft. c. In a private letter, recently received, Kalitin attributes his high values to low atmospheric transmissibility for solar radiation (0.793 on June 24, 0.742 on June 28, and 0.716 on June 29, the day of the eclipse). Generally, low transmissibility is due principally to increased atmospheric scattering of the solar rays, which gives increased intensity to diffuse skylight.—*H. H. K.*

[3] Kimball, Herbert H. and Hand, Irving F. Daylight Illumination on Horizontal, Vertical, and Sloping Surfaces. Mo. Wea. Rev., 50 : 618, 1922.

BIBLIOGRAPHY

C. FITZHUGH TALMAN, in Charge of Library

NOTE.—This section will be resumed in the next issue (May).—ED.

SOLAR OBSERVATIONS

SOLAR RADIATION MEASUREMENTS MADE DURING APRIL, 1929

By HERBERT H. KIMBALL

For reference to descriptions of instruments and exposures, and an account of the method of obtaining and reducing the measurements, the reader is referred to the January, 1929, REVIEW, page 26.

Table 1 shows that solar radiation intensities averaged close to normal values for April at Washington and below normal values at Madison and Lincoln.

Table 2 shows an excess in the total radiation received on a horizontal surface at Chicago, and a deficiency at Washington, Madison, Lincoln, and New York.

Skylight polarization measurements obtained on four days at Washington give a mean of 58 per cent with a maximum of 62 per cent on the 2d. These are close to the corresponding averages for April at Washington. At Madison measurements obtained on five days give a mean of 63 per cent, with a maximum of 67 per cent on the 13th. These are close to the corresponding averages for April at Madison.

TABLE 1.—*Solar radiation intensities during April, 1929*

[Gram-calories per minute per square centimeter of normal surface]

Washington, D. C.

Date	Sun's zenith distance: 8 a.m.	78.7°	75.7°	70.7°	60.0°	0.0°	60.0°	70.7°	75.7°	78.7°	Noon
	75th mer. time	Air mass: A. M.					P. M.				Local mean solar time
	e.	5.0	4.0	3.0	2.0	[1] 1.0	2.0	3.0	4.0	5.0	e.
	mm.	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*mm.*
Apr. 2	4.57	0.71	0.84	0.93	1.26	1.34	1.11	0.89	.....	.....	2.74
Apr. 3	6.76	.....	0.66	0.78	0.98	1.22	.....	.....	.....	.....	4.75
Apr. 12	6.50	.....	.....	.....	.....	1.38	.....	.....	.....	.....	6.76
Apr. 13	7.57	.....	.....	.....	.....	1.24	.....	.....	.....	.....	7.87
Apr. 19	3.45	.....	0.74	0.99	1.12	1.44	.....	.....	.....	.....	3.45
Apr. 20	5.36	.....	.....	0.77	1.03	1.27	.....	.....	.....	.....	6.27
Apr. 23	4.17	.....	0.83	1.02	1.17	1.41	.....	.....	.....	.....	3.15
Apr. 24	6.02	.....	.....	.....	0.95	.....	.....	.....	.....	.....	7.04
Apr. 27	7.29	.....	.....	.....	0.99	.....	.....	.....	.....	.....	6.27
Apr. 29	4.57	.....	.....	.....	1.30	1.43	1.21	1.02	.....	.....	3.99
Means	.....	(0.71)	0.77	0.90	1.10	1.34	(1.16)	(0.96)	.....	.....	.....
Departures	.....	±0.00	+0.01	±0.00	+0.02	−0.02	+0.06	+0.05	.....	.....	.....

[1] Extrapolated.

TABLE 1.—*Solar radiation intensities during April, 1929*—Contd.

[Gram-calories per minute per square centimeter of normal surface]

Madison, Wis.

Date	Sun's zenith distance: 8 a.m.	78.7°	75.7°	70.7°	60.0°	0.0°	60.0°	70.7°	75.7°	78.7°	Noon
	75th mer. time	Air mass: A. M.					P. M.				Local mean solar time
	e.	5.0	4.0	3.0	2.0	1.0	2.0	3.0	4.0	5.0	e.
	mm.	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*mm.*
Apr. 2	4.57	.....	.....	.....	1.25	.....	1.19	.....	.....	.....	3.45
Apr. 13	4.17	.....	.....	1.08	1.27	1.48	.....	.....	.....	.....	3.63
Apr. 15	4.17	.....	.....	1.07	1.23	1.47	.....	.....	.....	.....	4.17
Apr. 18	3.00	.....	.....	.....	1.25	1.55	.....	.....	.....	.....	3.15
Apr. 22	4.75	.....	0.89	1.01	1.13	1.39	.....	.....	.....	.....	3.81
Apr. 26	4.95	.....	0.67	0.81	1.04	1.30	.....	.....	.....	.....	5.56
Apr. 29	3.63	.....	.....	.....	1.17	.....	.....	.....	.....	.....	3.63
Means	.....	.....	0.78	0.99	1.19	1.44	(1.19)	.....	.....	.....	.....
Departures	.....	.....	−0.21	−0.09	−0.03	+0.02	−0.03	.....	.....	.....	.....

Lincoln, Nebr.

Apr. 2	3.81	0.60	.....	.....	1.16	1.47	1.14	.....	.....	.....	4.75
Apr. 8	4.57	.....	.....	.....	.....	.....	1.17	1.06	0.98	0.69	2.87
Apr. 12	3.81	.....	.....	0.92	1.15	.....	1.13	.....	.....	.....	5.59
Apr. 16	6.50	.....	.....	.....	1.21	.....	.....	.....	.....	.....	3.81
Apr. 17	3.43	0.70	0.88	1.01	.....	.....	.....	.....	.....	.....	6.02
Apr. 26	3.43	0.59	0.79	.....	.....	.....	.....	.....	.....	.....	3.43
Apr. 28	6.27	.....	.....	.....	.....	.....	1.08	1.00	0.84	0.69	4.95
Apr. 29	6.27	.....	.....	0.92	1.14	1.39	.....	.....	.....	.....	6.50
Apr. 30	3.81	.....	.....	0.80	.....	.....	.....	.....	.....	.....	5.59
Means	.....	0.63	(0.84)	0.91	1.16	(1.43)	1.13	(1.03)	(0.91)	(0.69)	.....
Departures	.....	−0.10	±0.00	−0.07	−0.05	−0.02	−0.05	+0.04	+0.05	−0.03	.....

TABLE 2.—*Solar and sky radiation received on a horizontal surface*

[Gram-calories per square centimeter of horizontal surface]

Week beginning—	Average daily radiation: Washington	Madison	Lincoln	Chicago	New York	Twin Falls	Fresno	Average daily departure from normal: Washington	Madison	Lincoln	Chicago	New York
	cal.	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*
Apr. 2	456	423	456	330	270	280	434	+66	+46	+39	+41	−59
Apr. 9	247	384	306	309	152	(1)	606	−149	−20	−109	±0	−185
Apr. 16	317	372	350	353	160	466	571	−102	−32	−88	+45	−164
Apr. 23	419	316	421	292	341	553	631	+1	−112	−55	−8	+12
Excess or deficiency since first of year on Apr. 29, 1929	.....	.....	.....	.....	.....	.....	.....	−1,197	−1,841	−4,319	+1,519	−2,737

[1] Incomplete record.

POSITIONS AND AREAS OF SUN SPOTS

[Communicated by Capt. C. S. Freeman, Superintendent U. S. Naval Observatory. Data furnished by Naval Observatory, in cooperation with Harvard, Yerkes, and Mount Wilson Observatories. The differences of longitude are measured from central meridian, positive west. The north latitudes are plus. Areas are corrected for foreshortening and are expressed in millionths of sun's visible hemisphere. The total area, including spots and groups, is given for each day in the last column]

Date	Eastern standard civil time	Heliographic			Area		Total area for each day
		Diff. long.	Longitude	Latitude	Spot	Group	
1929	h. m.	°	°	°			
Apr. 1 (Naval Observatory).	13 56	−66.0	97.1	−10.0		386	
		−42.5	120.6	−2.5		34	
		+35.0	198.1	+8.5		19	
		+56.0	219.1	+10.5		201	
		+57.5	220.6	−13.0		46	686
Apr. 2 (Naval Observatory).	11 46	−54.5	96.6	−10.0		370	
		−29.5	121.6	−2.5		19	
		+49.0	200.1	+8.5	9		
		+66.5	217.6	+10.5		123	
		+70.5	221.6	−13.5	56		577
Apr. 3 (Naval Observatory).	11 44	−47.5	90.4	+22.5	15		
		−41.5	96.4	−9.5		262	
		+58.5	196.4	+8.5	46		
		+79.0	216.9	+11.0		108	431
Apr. 4 (Naval Observatory).	11 28	−48.0	76.9	−8.5	9		
		−31.0	93.9	−17.5	9		
		−28.5	96.4	−9.5	231		
		+70.0	194.9	+8.5		93	342
Apr. 5 (Naval Observatory).	12 50	−31.0	79.9	−8.5		170	
		−15.0	95.9	−10.0		185	
		−3.5	107.4	−10.5		15	370
Apr. 6 (Naval Observatory).	11 38	−17.5	80.9	−8.5		355	
		−4.5	93.9	−17.5		40	
		−2.5	95.9	−10.0		154	
		+11.0	109.4	−11.5	9		558
Apr. 7 (Naval Observatory).	11 27	−5.5	79.7	−9.0		448	
		+10.5	95.7	−17.5		46	
		+10.5	95.7	−10.5		123	617
Apr. 8 (Naval Observatory).	11 35	+8.0	80.0	−9.0		432	
		+24.0	96.0	−17.0		19	
		+24.0	96.0	−10.0		123	574
Apr. 9 (Naval Observatory).	12 7	−76.5	342.0	+6.5	154		
		−32.0	26.5	−14.0		15	
		+22.5	81.0	−8.5		432	
		+36.5	95.0	−10.5	62		663
Apr. 10 (Mount Wilson).	18 30	−63.0	338.8	+7.0		361	
		−18.0	23.8	−15.0		4	
		+3.0	44.8	−20.5		4	
		+39.0	80.8	−10.0		538	
		+52.0	93.8	−10.5	57		
		+65.0	106.8	−12.0		75	1,059
Apr. 11 (Harvard)	11 51	−79.0	313.5	+8.5	259		
		−50.5	342.0	+6.5		405	
		+14.5	47.0	−20.0		132	
		+49.5	82.0	−9.5		763	
		+63.5	96.0	−11.0	71		
		+75.0	107.5	−12.0		216	1,846
Apr. 12 (Naval Observatory).	11 48	−66.5	312.6	+8.5	123		
		−38.0	341.1	+6.0		309	
		+26.0	45.1	−21.0		216	
		+63.0	82.1	−9.5		401	1,049
Apr. 13 (Naval Observatory).	11 34	−77.5	288.5	−9.5		170	
		−54.0	312.0	+8.0	139		
		−25.5	340.5	+5.5		262	
		+39.0	45.0	−20.5		170	
		+76.0	82.0	−10.0		324	1,065
Apr. 14 (Naval Observatory).	12 30	−64.0	288.3	−9.0		185	
		−39.5	312.8	+8.0	123		
		−12.0	340.3	+5.5		262	
		+53.0	45.3	−20.0		170	
		+62.0	54.3	−10.0		77	817
Apr. 15 (Harvard)	16 41	−50.0	287.0	−6.5	24		
		−44.5	292.5	−9.0		170	
		−20.5	316.5	+8.5	243		
		−7.5	329.5	+5.0	274		711
Apr. 16 (Mount Wilson).	13 0	−35.0	290.6	−9.0		124	
		−16.0	309.6	+9.0		157	
		+16.0	341.6	+5.0	252		
		+76.0	41.6	−20.0	33		566
Apr. 17 (Mount Wilson).	12 0	−22.0	290.9	−8.0		76	
		−1.0	311.9	+9.0		138	
		+29.0	341.9	+5.0		265	479
Apr. 18 (Naval Observatory).	11 30	−9.5	290.5	−8.0		62	
		+6.5	306.5	+6.0		62	
		+12.5	312.5	+9.0	123		
		+42.5	342.5	+6.0	247		494

POSITIONS AND AREAS OF SUN SPOTS—Continued

Date	Eastern standard civil time	Heliographic			Area		Total area for each day
		Diff. long.	Longitude	Latitude	Spot	Group	
1929	h. m.	°	°	°			
Apr. 19 (Naval Observatory).	11 32	+3.5	290.3	−7.5		62	
		+22.5	309.3	+5.5		247	
		+26.5	313.3	+9.0	108		
		+56.5	343.3	+6.0	309		726
Apr. 20 (Naval Observatory).	11 32	−32.0	241.6	+9.5		46	
		+8.0	281.6	−10.0		40	
		+17.5	291.1	−7.5	31		
		+36.0	309.6	+5.5		401	
		+39.5	313.1	+9.0	123		
		+69.0	342.6	+6.0	278		919
Apr. 21 (Naval Observatory).	11 10	−18.5	242.1	+9.0		62	
		+31.0	291.6	−7.0	31		
		+50.5	311.1	+5.5		540	
		+52.5	313.1	+9.0	123		
		+83.0	343.6	+5.5	185		941
Apr. 22 (Naval Observatory).	15 12	−17.5	227.7	+13.5		6	
		−1.5	243.7	+8.5		28	
		+45.5	290.7	−6.5	12		
		+65.5	310.7	+5.5		602	
		+67.0	312.2	+9.0	123		771
Apr. 23 (Naval Observatory).	11 47	+11.0	244.8	+8.0		31	
		+57.0	290.8	−6.5	15		
		+78.0	311.8	+5.5		509	
		+80.0	313.8	+9.0	123		678
Apr. 24 (Naval Observatory).	11 49	−84.0	136.6	+13.0	185		
		+17.0	237.6	−6.5		25	
		+23.0	243.6	+8.5		154	
		+87.5	308.1	+6.0	185		549
Apr. 25 (Naval Observatory).	16 24	−67.5	137.3	+13.5	154		
		+40.5	245.3	+8.5		355	509
Apr. 26 (Naval Observatory).	11 36	−58.0	136.3	+13.0		170	
		+52.5	246.8	+8.5		309	479
Apr. 27 (Naval Observatory).	11 36	−85.0	96.1	−9.0	154		
		−44.5	136.6	+13.5	170		
		+61.5	242.6	−5.5		31	
		+66.5	247.6	+8.5		247	602
Apr. 28 (Mount Wilson).	17 30	−74.0	90.6	−9.0		407	
		−66.0	98.6	−1.0		10	
		−28.0	136.6	+13.0		222	
		+78.0	242.6	−7.0		15	
		+85.0	249.6	+9.0	37		691
Apr. 29 (Naval Observatory).	11 42	−66.0	88.6	−20.0		62	
		−62.0	92.6	−8.5		278	
		−56.5	98.1	−1.5		77	
		−17.5	137.1	+14.5		108	525
Apr. 30 (Naval Observatory).	11 42	−54.5	86.9	−21.0		216	
		−48.5	92.9	−9.0		231	
		−40.0	101.4	−1.5		139	
		−4.5	136.9	+14.5		62	648
Mean daily area for April.							698

PROVISIONAL SUN-SPOT RELATIVE NUMBERS FOR APRIL, 1929

[Data furnished through the courtesy of Prof. W. Brunner, University of Zurich, Switzerland]

April, 1929	Relative numbers	April, 1929	Relative numbers	April, 1929	Relative numbers
1	47	11	(1)	21	
2	51	12	73	22	47
3	46	13	[1] 59	23	48
4	32	14	71	24	36
5		15	[2] 59	25	[1] 40
6	M [3 2] 63	16	62	26	44
7	[2] 54	17	M [2 3] 47	27	43
8	[4] 61	18	[2] 50	28	[1] 36
9	[1] 65	19	58	29	E [3 3] 38
10	M [3] 76	20	E [3] 62	30	53

Mean (27 days) = 52.6.

[1] Entrance of large or average-sized center of activity on the east limb.
[2] Passage of an average-sized group through the central meridian.
[3] New formation of a large or average-sized center of activity. E: on the eastern part of the sun's disk; W: on the western part; M: in the central zone.
[4] Passage of a large group through the central meridian.

AEROLOGICAL OBSERVATIONS

By L. T. SAMUELS

Free-air temperatures for the month were mostly above normal with departures of moderate magnitude. (Table 1.) Relative humidity averaged close to normal and the vapor pressures were mostly above normal in harmony with the temperatures. Resultant winds for the month at the surface were mostly southerly and the velocities very light. (Table 2.) At 1,000 meters a pronounced westerly component is found and the resultant velocities range from 5 to 10 m. p. s. At 4,000 meters the resultant direction is practically due west and the velocities mostly between 10 and 15 m. p. s.

A kite record obtained at Ellendale on the 5th is of particular interest in that it showed conditions in the northeast sector of a deep LOW (29.16 at Miles City, Mont.). North-northeast surface winds (6 m. p. s.) veered to east-southeast (19 m. p. s.) at the maximum altitude (3,623 m.). Light rain was falling from A. St. clouds whose base was about 100 meters higher. The following lapse rates, (° C./100 m.) prevailed, viz., 0.88°, surface to 560 m., −7.15° to 760 m., 0.44° to 1,450 m., 0.95° to 2,500 m., and 0.77° to 3,600 m.

The principal features are the pronounced inversion between 560 and 760 meters and the abnormally steep lapse rate between 1,450 and 2,500 meters (normal, 0.54°). In marked contrast to this steep lapse rate, viz, 0.87° between 1,450 and 3,600 meters in the northeast sector of this LOW, a considerably smaller lapse rate (0.49°) occurred on the 10th when easterly winds, likewise, extended to 3,800 meters, with the A. St. base at 4,700 meters. On the latter date, however, the station was under the influence of a HIGH centered to the northeast.

Conditions of unusual interest occurred at Broken Arrow on the afternoon of the 24th in connection with the passage of a wind-shift line while a kite flight was in progress. The station was in the south sector of a deep LOW (29.24 inches North Platte) and the following note was made by Mr. P. P. Hemphill, the observer making the flight:

As the Cu. Nb. moved out the sky became visible and appeared to have a reddish tinge that seemed to be following the path of the Cu. Nb. Soon the sky was overcast with this haze or dust. The sky had the appearance of a west Texas sky just in advance of an approaching sand storm. At 3:50 p. m. the surface humidity dropped almost instantly from 72 to 19 per cent and the temperature rose 3.6° C. at the same time. The wind veered from SE. to W., backed to SW., and then veered to NW. at 7:09 p. m. This condition prevailed until between 7 and 8 p. m., when the haze began to disappear and the humidity to rise.

The dry and warm southwesterly wind in the rear of this LOW occurred at the 1,000 meter level at least one hour before it came to the surface. Surface and free-air temperatures rose from 5° to 6° C. within one hour throughout the first 1,000 meter stratum of air, with the onslaught of this westerly air, and the relative humidity dropped from saturation to between 10 and 20 per cent.

CORRECTION

In Table 1 for March, 1929, the departures indicated for the 2,000 meter level and above were inadvertently based on normals which were from 1° to 4° C. too high. This error was a result of the change beginning with that month in omitting certain intermediate levels in this table. The corrected values show small to moderate positive temperature and vapor pressure departures at practically all stations and levels and mostly negative relative humidity departures. Anyone desiring to make use of this table can obtain the corrected departures upon application to the Aerological Division, Weather Bureau, Washington, D. C.

TABLE 1.—*Free-air temperatures, relative humidities, and vapor pressures during April, 1929*

TEMPERATURE (°C.)

Altitude m. s. l.	Broken Arrow, Okla. (233 meters)		Due West, S. C. (217 meters)		Ellendale, N. Dak. (444 meters)		Groesbeck, Tex. (141 meters)		Royal Center, Ind. (225 meters)		Washington, D. C.[1] (7 meters)	
	Mean	Departure from normal	Mean	Departure from normal	Mean	Departure from normal	Mean	Departure from normal	Mean	Departure from normal	Mean	Departure from normal
Meters												
Surface	17.2	+1.6	17.6	+0.8	4.8	−0.8	18.5	+0.5	12.2	+1.8	16.0	+3.3
500	15.5	+1.6	16.3	+1.9	4.4	−0.8	16.7	+1.0	9.5	+1.6	12.9	+3.7
1,000	13.0	+1.5	13.5	+1.8	2.7	0.0	15.2	+1.2	6.8	+1.3	10.8	+4.3
1,500	10.7	+1.3	10.4	+1.5	1.1	+0.6	13.6	+0.8	4.0	+0.7	8.4	+4.4
2,000	8.4	+1.3	7.6	+1.6	−1.7	+0.4	11.4	+0.7	1.5	+0.6	6.0	+4.1
2,500	5.6	+1.4	5.5	+1.9	−5.0	−0.1	8.3	+0.2	−1.1	+0.6	3.6	+3.6
3,000	2.7	+1.6	2.8	+1.8	−8.3	−0.4	4.9	−0.3	−4.3	0.0	0.1	+2.7
4,000	−3.1	+1.9	−2.0	+2.2	−14.6	−0.5	−2.5	−1.4	−11.0	−1.5		
5,000							−8.7	−1.8				

RELATIVE HUMIDITY (%)

Surface	67	+3	67	+5	69	+4	77	+4	69	+4	60	0
500	67	+4	62	0	69	+5	73	+2	72	+7	57	−2
1,000	66	+6	62	+1	62	+2	60	−2	73	+11	54	−3
1,500	61	+6	63	+3	55	−2	48	−1	71	+12	57	−1
2,000	55	+5	56	−1	54	−1	40	−3	67	+10	58	+1
2,500	58	+9	51	0	53	−1	38	−3	62	+10	54	−1
3,000	48	0	49	+1	55	+1	35	−5	67	+17	54	+1
4,000	14	−31	49	+5	59	+3	35	−8	68	+19		
5,000							3	−36				

VAPOR PRESSURE (*mb.*)

Surface	13.62	+1.78	13.38	+1.30	5.86	+0.02	17.07	+1.63	10.43	+1.80	11.73	+2.30
500	12.27	+1.87	11.65	+1.09	5.71	+0.03	14.10	+1.03	9.10	+1.74	9.17	+1.69
1,000	10.30	+1.91	9.75	+0.89	4.41	−0.12	10.26	+0.12	7.66	+1.67	7.44	+1.33
1,500	8.20	+1.53	8.06	+0.89	3.61	−0.09	7.19	+0.04	6.39	+1.45	6.69	+1.36
2,000	6.16	+1.06	5.71	+0.32	3.00	+0.04	5.03	−0.32	4.58	+0.58	5.80	+1.29
2,500	5.41	+1.32	4.28	+0.34	2.41	+0.02	3.68	−0.58	3.73	+0.68	4.56	+0.90
3,000	3.76	+0.49	3.40	+0.39	2.00	+0.08	2.51	−0.92	3.21	+0.80	3.30	+0.57
4,000	0.50	−1.51	2.41	+0.57	1.44	+0.18	1.19	−1.15	1.67	+0.04		
5,000												

[1] Naval air station.

TABLE 2.—*Free-air resultant winds (meters per second) based on pilot balloon observations made near 7 a. m. (E. S. T.) during April, 1929*

Altitude m. s. l.	Broken Arrow, Okla. (233 meters)		Burlington, Vt. (132 meters)		Cheyenne, Wyo. (1,868 meters)		Due West, S. C. (217 meters)		Ellendale, N. Dak. (444 meters)		Groesbeck, Tex. (141 meters)		Havre, Mont. (762 meters)		Jacksonville, Fla. (65 meters)		Key West, Fla. (11 meters)		Los Angeles, Calif. (40 meters)	
	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity
Meters	°		°		°		°		°		°		°		°		°		°	
Surface	S 6 E	1.7	S 57 W	1.4	N 67 W	2.7	S 58 W	0.9	N 23 W	1.4	S 18 E	1.7	N 84 W	0.5	S 42 W	1.3	S 47 E	2.2	N 62 E	1.6
500	S 18 W	5.6	S 49 W	3.2			S 67 W	5.1	N 19 W	1.3	S 13 E	4.9			S 40 W	3.1	S 50 E	5.0	S 27 E	1.3
1,000	S 40 W	9.1	S 74 W	3.6			S 85 W	7.3	N 74 W	1.8	S 6 W	3.0	S 61 W	2.9	S 45 W	3.5	S 50 E	3.2	N 64 W	0.5
1,500	S 78 W	9.3	N 74 W	5.9			W	6.2	N 80 W	3.4	N 42 W	4.0	S 85 W	4.7	N 86 W	2.8	S 29 E	1.5	N 19 W	2.0
2,000	S 87 W	10.3	N 74 W	10.0	N 76 W	5.7	N 79 W	7.7	N 71 W	5.1	N 75 W	1.8	S 88 W	5.1	N 82 W	3.7	S 12 W	1.4	N 40 W	3.4
2,500	S 85 W	11.0	N 50 W	12.7	N 85 W	10.8	N 79 W	8.9	N 74 W	6.9	S 83 W	4.7	S 89 W	6.1	N 87 W	5.6	S 52 W	1.6	N 48 W	5.6
3,000	N 87 W	10.3	N 48 W	14.5	N 80 W	13.0	N 77 W	8.3	N 66 W	6.7			S 88 W	6.1	S 85 W	4.3	N 76 W	1.7	N 58 W	7.7
4,000	N 83 W	12.7	N 48 W	13.6	N 69 W	12.1	N 75 W	11.3	N 60 W	8.5			N 70 W	9.7	N 77 W	6.7	N 58 W	4.0	N 68 W	9.8
5,000					N 73 W	9.4	N 85 W	9.2	N 67 W	11.9			N 83 W	9.8	N 74 W	7.9	N 60 W	6.9		

Altitude m. s. l.	Medford, Oreg. (446 meters)		Memphis Tenn. (145 meters)		New Orleans, La. (25 meters)		Omaha, Nebr. (313 meters)		Royal Center, Ind. (225 meters)		Salt Lake City, Utah (1,280 meters)		San Francisco, Calif. (60 meters)		Sault Ste. Marie, Mich. (198 meters)		Seattle, Wash. (67 meters)		Washington, D. C. (34 meters)	
	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity
Meters	°		°		°		°		°		°		°		°		°		°	
Surface	S 65 E	0.3	S 8 E	2.6	S 73 E	0.7	N 3 W	0.3	S 34 W	1.2	S 44 E	1.1	N 89 W	1.1	N 9 E	1.2	S 40 E	2.6	N 54 W	0.9
500	S 68 W	0.2	S 33 W	6.5	S 17 E	5.8	S 20 W	1.2	S 57 W	3.8			N 78 W	3.2	N 40 E	1.6	S 22 W	2.8	N 76 W	5.4
1,000	S 76 W	1.6	S 64 W	7.8	S 21 W	5.4	S 34 W	3.4	N 84 W	5.7			N 68 W	4.9	N 20 W	1.9	S 57 W	3.9	N 75 W	10.0
1,500	S 40 W	2.2	S 88 W	7.8	S 25 W	4.3	S 76 W	3.4	N 74 W	6.0	S 29 E	2.4	N 61 W	3.4	N 37 W	3.3	S 74 W	2.1	N 77 W	10.6
2,000	S 57 W	4.1	S 87 W	6.2	S 65 W	3.6	N 74 W	5.8	N 74 W	8.4	S 65 W	1.8	N 56 W	3.1	N 12 E	5.3	N 64 W	4.2	N 69 W	11.1
2,500	S 72 W	4.2	N 72 W	8.2	N 85 W	3.7	N 72 W	7.7	N 72 W	9.4	N 81 W	3.0	N 67 W	5.8	N 19 E	3.6	N 60 W	4.0	N 66 W	10.6
3,000	S 75 W	5.1	N 64 W	10.0	N 89 W	5.4	N 74 W	10.2	N 65 W	11.6	N 76 W	6.2	N 65 W	7.0	N 10 W	6.2	N 61 W	4.1	N 79 W	10.4
4,000					S 86 W	6.8	N 80 W	14.9			N 80 W	8.0	S 89 W	7.5						
5,000					N 70 W	9.0														

WEATHER IN THE UNITED STATES

THE WEATHER ELEMENTS

By P. C. DAY

GENERAL CONDITIONS

April, 1929, like the preceding month, continued moderately warm over most districts from the Rocky Mountains eastward and also like March it continued cool to the westward. The precipitation was generally greater than normal, except over portions of the Southwest and near-by areas in the west Gulf section and locally in some other small areas, aggregating about one-fourth of the country with precipitation less than normal.

PRESSURE AND WINDS

The month opened with a well-defined cyclonic storm central over lower Michigan, attended by heavy snows or rains and snows over portions of the Lake region and upper Mississippi Valley and by precipitation generally from the middle and northern Plains eastward to the Appalachian Mountains, continuing during the following day into the more northeastern States. Generally fair weather prevailed thereafter until the 4th, when rain set in over the Pacific Coast States, extending during the 5th into most districts to westward of the Rocky Mountains and changing to snow in some of the elevated districts. At the same time conditions favoring local thunderstorms overspread the region from the Ohio Valley and eastern Lake region to the middle Atlantic coast, continuing over some of this area during the following day and extending westward into the upper Mississippi Valley and portions of the Northwest, the western precipitation area having largely broken up on reaching the Great Plains.

At the a. m. observation of April 8, thunderstorm conditions existed over a narrow area from the lower Rio Grande Valley northeastward to the Great Lakes, attended by local heavy rains in portions of Missouri and Texas, and during the following 24 hours the rain area extended slightly eastward, the heavy falls occurring mostly in eastern Texas and portions of the lower Mississippi Valley. During this period low barometric pressure was developing in the far Southwest and by the morning of the 10th it had extended to the southern Plains, while the area favorable to thunderstorms had advanced to North Carolina, and at 8 a. m. of the 10th precipitation had overspread a wide area from the northern and central mountains southeastward nearly or quite to the middle and south Atlantic coasts, considerable snow occurring over the mountain States with more or less heavy rains in the Ohio Valley. The eastern precipitation area practically disappeared by the 11th, but the center of the Plains area had moved northeastward to the upper Mississippi Valley and local rains continued over wide areas in the central valleys and toward the Atlantic coast.

During the following 24 hours, local rains continued in the Lake region and generally from the middle Gulf eastward to the Atlantic coast and thence northward to southern New England, the storm disappearing during the following day to northward of the Great Lakes with some snow occurring in the northern portions of New York and New England.

About the 14th and 15th precipitation overspread considerable portions of the far Northwest and at the same time cyclonic conditions developed in the Southwest, which, by the morning of the 15th, had reached the Middle Gulf States and heavy rains had occurred locally in the area affected. This storm moved to the immediate middle Atlantic coast by the 16th and heavy rains had extended into portions of this area, the precipitation area passing off the New England coast attended by local snows in the elevated regions of the Northeastern States.

After a considerable period without important precipitation over the Pacific coast, about the 19th and during

the following few days more or less precipitation occurred over the region extending eastward into the Middle Plateau and Rocky Mountain section, and by the morning of the 20th the rain area had reached the central valleys with local heavy falls in portions of the upper Mississippi Valley and near-by areas. During the following day this rain area passed off the north Atlantic coast with diminishing intensity.

By the 24th a cyclone of considerable strength had entered over the middle Plains, moving thence to the southern end of Lake Michigan by the 25th, with very general rains over the central valleys and to near the Atlantic, passing, during the following day, to northen New England with general, but moderate precipitation.

During the 28th and 29th considerable rainfall overspread the eastern one-third of the country and on the 30th some rain fell over the northern districts from Washington eastward to the Great Lakes and over the northern portions of New York and New England.

The most important anticyclone of the month had overspread the southern Plains by the morning of the 1st, attended by changes to colder of 20° to 30° over a considerable area in the Southwest. As this anticyclone moved eastward it was attended by some of the coldest weather of the month, particularly from the Great Plains eastward to the Mississippi Valley and northeastward to New England. The next important anticylcone moved into the Dakotas on the morning of the 8th and passed eastward over the more northern districts, but without important temperature changes. The latter part of the month had much cool weather, but the changes from day to day were mainly unimportant, though during the last decade some of the lowest temperatures of the month occurred.

The average sea-level pressures were less than normal in practically all parts of the country, and the changes from the preceding month were negative save along the extreme northern border and over the adjacent portions of Canada.

Storms of the thunderstorm type became more numerous, as is usually the case with the approach to summer, and a number of these took on the tornado type and caused material property damage and the loss of nearly 200 lives, these occurring mainly in Georgia, Arkansas, and Wisconsin. The details of these storms appear in the table at the end of this section.

TEMPERATURE

The month opened with decidedly cold weather advancing eastward over the Great Plains, the cold area reaching the Atlantic coast districts by the morning of the 2d, after which there was a quick rise to the general warmth that had prevailed during much of the latter part of March over these districts.

The first week as a whole averaged well above the normal in all these districts, the averages being especially high from the middle Plains eastward, where they ranged from 10° to 20° or more above the normal. West of the Rocky Mountains this period was distinctly cool, the averages ranging largely from 6° to 12° below the normal.

The week ending the 16th began with cooler weather existing in nearly all central and western districts, but high temperatures still persisted in the East and Southeast until about the 11th when cooler weather set in over those districts, and moderate coolness persisted in many districts until the end of that week, the averages for the period being below normal over all sections save from Texas eastward over the Gulf and South Atlantic States where they ranged up to as much as 6° above the normal.

During the week ended April 23 there were no important temperature changes, the averages being moderately lower than normal from the middle Plains eastward, while they continued slightly warmer than normal in the west Gulf area and was also moderately warmer than normal over the Plateau and Rocky Mountain areas, and slightly cooler than normal over most of the Pacific coast area.

The last week of the month showed no radical departures of temperature from the normal, the week being moderately cool in most districts, though the weekly means continued above normal in most of the Gulf States and over the Great Plains area.

The month, as a whole, was warmer than normal from the Great Plains eastward, save for a small area in New England, and cooler in the Rocky Mountain area and to the westward, while the eastern Provinces of Canada were generally warmer and the western Provinces cooler than normal.

The monthly means of temperature at Corpus Christi, and Galveston, Tex., and Norfolk, Va., were the highest of record for April, while in portions of Oregon they were among the lowest ever observed.

Many stations in the central and eastern parts of the country had unusually high temperatures during the first decade, particularly about the 6th to 8th, when, at some points, they were the highest of record so early in the season. At New Orleans, La., the maximum temperature on the 25th, 90°, was the highest of record in April.

The periods of lowest temperatures were mainly on the 1st and 2d over the northeast, middle Plains, upper Mississippi Valley, and along the northern border to the eastward; about the 10th to 12th in the Mountain and Pacific Coast States; and the 16th to 18th in the Gulf and South Atlantic States and Ohio Valley.

A minimum temperature of 37.8° on the morning of April 8, at Yuma, Ariz., was the lowest ever observed in April at that place in more than 60 years.

PRECIPITATION

The distribution of the monthly precipitation is graphically shown on Chart V, and the departures from normal values are shown on the small inset to that chart.

Generally speaking, precipitation was in excess of the normal over middle and northern portions and slightly deficient in most southern sections. The excesses were large from the Great Lakes eastward and over most of Missouri and portions of near-by States, the total falls being the greatest of record for April at numerous points in the Northeastern States. In portions of northwestern Texas the precipitation was the least of record for April, while at a few points in the eastern part of that State heavy thunderstorms on the 13th broke all previous records of excessive precipitation for short periods of time.

SNOWFALL

Snowfall occurred in varying amounts ranging from 73 inches in some of the high mountains of the far Northwest to the usual traces in the central parts of the country.

At a few places the amounts were unusually heavy, notably in northern New England on the 12th and 13th, when 17 inches fell at Northfield, and in Wyoming, where, in the vicinity of Cheyenne, 11 inches of wet, heavy snow fell on the 23d and 24th, causing much delay in transportation and damage to overhead wires, and similar falls occurred in other parts of the State about the same time,

likewise tying up transportation and causing immense damage to wire systems.

Heavy snow, sleet, and glaze occurred in portions of Wisconsin and Michigan from the storm of March 31–April 1, causing much damage to overhead wires, shade, fruit, and other trees.

At a few points, notably in Nevada, the snow was the heaviest of record for April, while at Red Bluff, Calif., snow on the 5th was the first ever observed in April.

RELATIVE HUMIDITY

As a rule, the percentages of relative humidity were above the average at most points to east of the Rocky Mountains, while to the westward they were mostly less, save along the immediate Pacific coast where they were again above the average.

Large negative departures are noted at points in New Mexico and some near-by areas and in eastern Washington, and local areas in southern Idaho and northern Utah had equally large positive departures. As a rule, however, the departures from normal were comparatively small.

SEVERE LOCAL STORMS, APRIL, 1929

[The table herewith contains such data as have been received concerning severe local storms that occurred during the month. A more complete statement will appear in the Annual Report of the Chief of Bureau]

Place	Date	Time	Width of path, yards [1]	Loss of life	Value of property destroyed	Character of storm	Remarks	Authority
Kentucky (western)	1				$25,000	Wind	Buildings destroyed or damaged; wire lines injured.	Official, U. S. Weather Bureau.
Louisville, Ky	1	A. M.			10,000	do	2 oil barges sunk; windows and buildings damaged.	Do.
Hardin County, Ohio	1	do				Wind and hail	Considerable losses; greenhouses suffered severely.	Do.
New York (mainly western, central, and northern).	1			1	400,000	Wind	Hangar and small buildings wrecked; houses unroofed; trees and wire lines blown down; docks and boathouses damaged.	Official, U. S. Weather Bureau. Courier Express (Buffalo, N. Y.).
Portland, Pa., to Blairstown, N. J.	1	4–5 p. m.	100	3	50,000	Tornado	30 buildings destroyed; several persons hurt. Path 8 miles long.	Official, U. S. Weather Bureau.
Ottawa to Rogers Counties, Okla.	3	12:15–12:45 p. m.	1,760		4,200	Severe hail	Greatest damage at Vinita. Path 35 miles long.	Do.
Lyon County, Iowa	5	3 p. m.		1	21,000	Tornado	Some hail with tornado	Do.
Hennepin County, Minn., to Polk County, Wis.	5	5:30 p. m.	200–440	6	1,000,000	do	Traversed part of Minneapolis. Path 70 miles long.	Do.
Pierce to Iron Counties, Wis.	5	5.45–8:30 p. m.	30–400	12	725,000	Tornado and hail	Losses chiefly farm buildings, livestock, wire lines. Path 170 miles long.	Do. Journal (River Falls, Wis.); News (Ladysmith, Wis.).
Hancock County, Iowa	5	6:30 p. m.			10,000	Tornado	4 persons hurt	Official, U. S. Weather Bureau.
Cloud and Washington Counties, Kans.	6	2:30–3:30 p. m.	200–880		40,000	do	Farm buildings and wire lines damaged. Path 45 miles long.	Do.
Cloud to Marshall Counties, Kans.	6	2:30–4:10 p. m.	1–5 mi.		60,000	Wind and hail	Embraced the tornado-swept area noted above.	Do.
Mitchell County, Kans.	6	3 p. m.	880		2,000	Heavy hail	Roofs and glass damaged. Path short	Do.
Iowa (east-central)	6	4–7 p. m.			5,800	Hail and wind	3 countries affected	Do.
Grant, Lafayette, and Green Counties, Wis.	6	4:30–6:20 p. m.	30–440		250,000	Tornado and hail	Losses chiefly in buildings, wire lines, livestock, and timber. Many injured. Path 50 miles long.	Do.
Union County, Iowa	6	7 p. m.			4,000	Tornado	No details reported	Do.
Warren County, Iowa	6	7:30 p. m.	30		3,400	do	8 persons hurt. Path 4 miles long	Do.
Jasper and Marshall Counties, Iowa.	6	do			25,000	do	1 person injured. Path 25 miles long	Do.
Perry, Okla., and vicinity	7	1–1:30 p.m.	3 mi.		22,000	Heavy hail	Damage chiefly to crops. Path 10 miles long	Do.
Chicago, Ill	7	7:45 p. m.			3,000	Small tornado	Path in south part; short and very narrow	Official, U. S. Weather Bureau.
McDonald County, Mo.	7	9 p. m.			600	Probably tornado	Some buildings damaged; no person harmed. Path narrow and 3 miles long.	Do.
Scurry, Tex	8	2 a. m.	800		3,500	Tornado	Buildings damaged	Do.
Ennis, Tex	8	3 a. m.	300			do	Destroyed small buildings; 1 person injured	Do.
Clarksville, Tex	8	5 a. m.	30			do	Small buildings damaged	Do.
Humble, Tex	8	11 p. m.			20,000	Wind	Oil derricks blown down	Chronicle (Houston, Tex.).
Lake Charles, La	9	2:30 a. m.			25,000	do	Oil equipment damaged	Official, U. S. Weather Bureau.
Clark County, Kans	9	4 p. m.				Small tornado	Touched ground but once	Do.
Kansas (northwest part)	9	4:30–7 p. m.				Heavy hail	Damage small, chiefly to fruit; 3 counties affected.	Do.
Chautauqua County, Kans.	9	8:30 p. m.			1,500	Small tornado	Path 15 miles long	Do.
Latham, Kans	9	11 p. m.	50		3,000	do	Path but half mile long	Do.
Neosho County, Kans	9–10	11 p. m.–2 a. m.			2,500	Heavy hail and small tornado.	Windows broken and automobile tops punctured by hail.	Do.
Calico Rock, Ark. (near)	10	3 p. m.	220			Tornado	Damage slight. Path 1 mile long	Do.
Troup, Tex	10	3:18 p. m.	2 mi.		23,500	Hail	Buildings and crops damaged. Path 11 miles long.	Do.
Almond to Moorefield, Ark.	10	4–4:20 p.m.	170		20,000	Tornado	Several injured. Path 14 miles long	Do.
Almond to Lorado, Ark	10	4–7:45 p.m.	200–1,200	31	308,000	do	Started near preceding; worst havoc near Swifton. Path 65 miles long.	Do.
Mount Pleasant, Ark	10	4:30 p. m.				do	Damage slight. Path narrow and short	Do.
Herpel to Mount Pleasant, Ark.	10	5 p. m.	300–400	7	216,000	do	Guion almost obliterated. Path 18 miles long	Do.
Alice, Tex	10	do	15			Small tornado	Destroyed poultry house	Do.
Diaz, Ark	10	6:20 p. m.	300		11,000	Tornado	2 persons hurt. Path 2 miles long	Do.
Monette, Ark	10	8 p. m.	220		40,000	do	Path 2 miles long	Do.
Wynne (near) to Parkin, Ark.	10	8–8:30 p.m.	100	18	200,000	do	Princedale suffered most. Path 16 miles long	Do.
Wynne, Ark	10					Hail	Considerable damage	Do.
Coffey County, Kans	10	8:15 p. m.	3–4 mi.			Heavy hail	Path 5 miles long	Do.
New Jersey coast	10–11				150,000	Gale	Surf high; houses swept away; boardwalk partly torn out. Northern Ocean County suffered most.	Do.
Ellis County, Okla	13	5 p. m.	5 mi.			Heavy hail	Damage considerable	Do.
Canadian County, Okla.	13	10–11 p. m.				do	Gardens and fruit trees suffered	Do.
Smithville, Tex	14	6:10 a. m.	400		75,000	Tornado	Several injured; buildings damaged	Do.

[1] "Mi" signifies miles instead of yards.

SEVERE LOCAL STORMS, APRIL, 1929—Continued

Place	Date	Time	Width of path, yards	Loss of life	Value of property destroyed	Character of storm	Remarks	Authority
Eastland and Comanche Counties, Tex.	14	4:30–5 p. m.			65,000	Hail	Livestock killed near De Leon; buildings and crops damaged.	Official, U. S. Weather Bureau.
Rusk, Gregg, and Harrison Counties, Tex.	14	5–8 p. m.	2–6 mi.		5,000	do	Poultry, glass, fruit, and crops suffered	Do.
Louisiana (southeastern)	14	5:30 p. m.			15,000	Hail and thundersquall.	Gardens and oranges damaged	Do.
Goodwell, Okla	14	7:15 p. m.	1½ mi.		500	Hail	Windows broken; roofs and auto tops damaged. Path 3 miles.	Do.
Louisiana (northwestern)	14	8–9 p. m.		1	6,000	Thundersquall	Buildings, windows, and trees suffered from Shreveport to Arcadia.	Times (Shreveport, La.).
Subiaco, Ark	14	P. m.				Tornado	Damage slight. Path narrow and short	Official, U. S. Weather Bureau.
Apalachicola, Fla. (near)	15	3 p. m.				Possibly tornado	Pine trees broken off; path one-fourth mile long	Do.
Anthony, Fla	15	7:30–8 p. m.	1¼–2 mi.		3,000	Heavy hail	Tomatoes and other crops suffered	Do.
New Jersey (mainly southern).	16				300,000	Gale	Buildings along seashore wrecked or damaged; buildings, trees, wire lines, and crops over State harmed.	Do.
Harper County, Okla	18	4–5 p. m.				Tornado	House demolished; farm machinery wrecked; 2 persons hurt.	Clark County Clipper (Ashland, Kans.).
Llano, Tex. (near)	18	5 p. m.	5 mi.			Hail	Poultry killed	Post-Dispatch (Houston, Tex.).
Belton, Tex	18	6:30 p. m.	1 mi.		10,000	do	Crops damaged	Official, U. S. Weather Bureau.
Dallas, Tex	19	4:42 a. m.			10,000	Wind	Small buildings, glass, and shrubbery damaged	Do.
Cowley County, Kans	19	4 p. m.	880		1,000	do	Barn destroyed; trees blown down. Path a mile long.	Do.
Duke, Okla	19	4:30–5 p. m.	4 mi.		15,000	Heavy hail	Crops greatly harmed. Path 10 miles long	Do.
Sumner County, Kans	19	5 p. m.	1 mi.		10,000	do	Gardens and fruit suffered. Path 3 miles long	Do.
Cleburne, Tex	19	6:30 p. m.	600	1	36,000	Tornado and hail.	Many houses destroyed; 2 persons injured	Do.
Kiowa and Caddo Counties, Okla.	19	7:30 p. m.	1 mi.			Hail, wind, and rain.	Path 13 miles long	Do.
Weatherford, Okla., and vicinity.	19	8:15 p. m.	1 mi.		5,000	Hail	Damage mainly to crops. Path 6 miles long	Do.
Paris, Tex	19	8:30 p. m.	100		40,000	Wind	Buildings damaged	Do.
Waxahachie, Tex. (near)	19		3 mi.			Hail	Livestock killed; crops damaged	Do.
Inman, S. C	19	11 p. m.			3,000	Thunderstorm	House fired and burned	Do.
Wilson County, Kans., to Bates County, Mo.	20	3–5 p. m.	30–440		175,000	Tornado	Some farms swept clean; 6 persons hurt. Path 70 miles.	Do.
Greenwood to Anderson Counties, Kans.	20	3:07–4:30 p. m.	30–170	1	75,000	do	Several funnel clouds at times. Path 70 miles long.	Do.
Buckner, Ark	20	3:30 p. m.			1,000	do	Path short	Do.
Barton and Vernon Counties, Mo.	20	4–5 p. m.	30–440		84,000	do	Funnel cloud noted over Kansas, but reached ground only in Missouri; a few persons hurt. Path 15 miles long.	Do.
St. Clair County, Mo	20	4–5 p. m.			1,500	Probably tornado	Farm buildings wrecked. Path very narrow, but 2 miles long.	Do.
Anderson County, Kans	20	4:30 p. m.			5,000	Small tornado	Damage to barns and a drilling rig. Path 8 miles long.	Do.
Polk and Hickory Counties, Mo.	20	5:30–6 p. m.	300–880		15,000	Tornado	Buildings and furniture destroyed; many hurt. Path 14 miles long.	Do.
Polk and Dallas Counties, Mo.	20	6 p. m.	100–300		171,000	do	Great havoc in Bolivar; many injured, some seriously. Path 24 miles long.	Do.
London, Ark	20	6:30 p. m.	100		9,000	do	Path short	Do.
Clinton, Ark	20	7:25 p. m.	200		11,000	do	do	Do.
Batesville, Ark. (near)	20	8:45 p. m.	75		13,000	do	A few persons injured. Path short	Do.
Jeffersonville and New Albany, Ind., and Louisville, Ky.	21	2:30–2:45 p. m.			100,000	Hail	Greenhouses, roofs, windows, and auto tops damaged; a few persons hurt. Havoc mainly in Indiana.	Do.
Alexander County, Ill., to Ballard County, Ky.	21	2:30–4:30 p. m.	4 mi.		60,000	Heavy hail	Roofs, hotbeds, and crops damaged. Path 30 miles long.	Do.
Tillar, Ark	21	2:45 p. m.		12	1,000	Tornado	2 houses wrecked. Path narrow, but 5 miles long.	Do.
Dahomy and Shaw, Miss.	21	3 p. m.		7		Probably tornado	Many seriously hurt; considerable property loss	Do.
Oak Ridge, La. (near)	21	3:45 p. m.	18–50	2	7,550	Tornado	Several houses demolished. Path 8 miles long	Do.
Springbank, Ark	21	9:10 p. m.			2,000	Heavy hail	Crops, roofs, and windows damaged	Times-Picayune (New Orleans, La.). Official, U. S. Weather Bureau.
Walton, Ky	21			2		Thunderstorm	Barn struck by lightning; several survivors shocked.	Official, U. S. Weather Bureau.
Tennessee	21					Thundersqualls and hail.	Houses unroofed; crops riddled; trees and fences blown down.	Do.
Extreme southern Ohio and central West Virginia.	21	P. m.			50,000	Hail and wind	Trees stripped, early crops beaten down, roofs cut, buildings unroofed, small structures and trees blown over. Havoc greatest in Gallia County, Ohio, and Randolph and Pocahontas Counties, W. Va.	Do.
Columbia, S. C	22	4 a. m.			3,200	Thundersquall and hail.	Plate glass and merchandise damaged	Do.
Charleston, S. C. (near)	22				20,000	Severe hail	Crops suffered	Do.
Frontier and Dawson Counties, Nebr.	23	11 p. m.			50,000	Tornado and downpour.	Farm buildings wrecked. Tornado path 10 miles long. Considerable flood damage.	Do.
Wyoming (southeastern)	23–24				300,000	Heavy snow	Wires prostrated; trees down; cars and automobiles stalled; some stock lost.	Do.
Harper County, Okla	24	1 a. m.				Tornado	Buildings and windmills destroyed or damaged; chickens killed. Path 14 miles long.	Clark County Clipper (Ashland, Kans.).
Slocum and Denson Spring, Tex.	24	12:20 p. m.	3 mi.	7	200,000	do	Slocum wiped out; scores of persons injured. Path fully 9 miles long.	Official, U. S. Weather Bureau.
Center, Tex. (near)	24	2:30 p. m.	800		125,000	do	Several persons hurt; buildings and crops damaged.	Do.
Butler County, Nebr	24	3 p. m.			75,000	do	Buildings wrecked; a few people hurt. Path 35 miles long.	Do.
Saunders and Sarpy Counties, Nebr.	24	4:40 p. m.			41,500	do	Buildings wrecked or damaged. Struck in 2 strips in path 20 miles long.	Do.
Bourbon County, Kans	24	6:30 p. m.	100		5,000	do	Farm buildings demolished or injured; 2 persons hurt. Path 6 miles long.	Do.
Winnsboro, La. (near)	24				12,000	Thundersquall	Damage to buildings and timber	Do.
Anderson and Spartanburg Counties, S. C.	25	3:50–4:30 p. m.	400–900	6	102,000	Tornado	Scores badly injured; buildings wrecked or damaged. Extreme limits of havoc 43 miles apart, but large gaps.	Do.
Sparta, Ga	25	4 p. m.				Possibly tornado	Houses demolished; one person hurt	Do.
Bleckley to Laurens Counties, Ga.	25	4:20–5 p. m.	150–400	11	330,000	Tornado and hail	Buildings wrecked; crops ruined; scores injured. Path 25 miles long.	Do.
York, Pa	25	8 p. m.	100		10,000	Possibly tornado	Several houses unroofed; wire lines broken	Do.
Candler and Bulloch Counties, Ga.	25	8:20 p. m.	100	40	1,020,000	Tornado and hail	Hundreds hurt; buildings demolished; stock killed; crops destroyed. Path 15 miles long.	Do.

SEVERE LOCAL STORMS, APRIL, 1929—Continued

Place	Date	Time	Width of path, yards	Loss of life	Value of property destroyed	Character of storm	Remarks	Authority
Norristown, Ga	25		200	2	50,000	Tornado and hail	Houses and crops suffered	Official, U. S. Weather Bureau.
Georgia (south-central part)	25				100,000	Heavy hail	Fruit and other crops greatly damaged. Houston and Tift Counties hard hit.	Do.
Churubusco, Ind	25				10,000	Possibly tornado	Garage destroyed; windows, poles, and fruit trees suffered.	Do.
Ohio (northeastern)	25					Heavy hail	Greenhouses, roofing, and auto tops damaged. Northern part of Wayne County hardest hit.	Do.
Akron to Ravenna, Ohio	25			3		Wind and electrical.	Roofs ripped off; outbuildings destroyed; trees flattened.	Standard Union (New York, N. Y.).
Moundsville, W. Va., and vicinity.	25				15,000	Hail and wind	Factory partly unroofed; glass broken	Official, U. S. Weather Bureau.
Louisa County, Iowa	27	7 p. m.	220		2,100	Tornado	No personal injuries reported	Do.
Kershaw County, S. C.	28	2:30 p. m.	100	1	5,000	do	Injuries to 12 persons	Do.
Cleveland, Ohio, and vicinity.	28	4–5 p. m.		1		Thundersquall and hail.	Windows blown in; boy drowned from upset sailboat. Marked wind damage at Parma Village, in tract 200 yards long and 75 yards wide.	Do.
Tom Green and Runnels Counties, Tex.	29	Noon	880		5,000	Hail and wind	Crops and livestock suffered; windmills blown down; houses unroofed.	Do.
Mercury, Tex	29	3 p. m.	6 mi.		30,000	Hail	Crops, buildings, and autos damaged	News (Dallas, Tex.).
Richards, Tex	29	5 p. m.	6 mi.		50,000	Wind	Losses mainly in crops and buildings. 3 persons hurt.	Official, U. S. Weather Bureau.
Bell County, Tex	29	5–5:30 p. m.	1–3 mi.		1,500	Wind and hail	Crops and buildings suffered	Do.
Doniphan County, Kans.	30	1 a. m.			1,000	Wind	Outbuildings destroyed; windows broken; wire lines down.	Do.
Mahaska and Keokuk Counties, Iowa.	30	6 a. m.			12,000	do	1 person hurt	Do.
Linn County, Iowa	30	7:30 a. m.			3,000	do	No details	Do.
Ionia County, Mich	30	4 p. m.				Electrical and tornadic wind.	Buildings razed; considerable damage from lightning.	Do.
Winneshiek County, Iowa	30	5 p. m.			4,000	Tornado	No details	Do.
Trempealeau, Wis	30	5:15 p. m.				Heavy hail	Apple buds and early vegetables suffered	Do.
Alabama (central and northeastern).	30				10,000	Hail	Garden truck injured; young cotton ruined locally.	Do.

RIVERS AND FLOODS

By H. C. FRANKENFIELD

The outstanding feature of the month of April was the great Mississippi flood. As shown in previous reports, the Mississippi River at the close of March, 1929, was in flood from Muscatine, Iowa, to Baton Rouge, La., and during the month of April the river continued above the flood stage from the mouth of the Ohio River southward, a primary crest of 18.4 feet passing Orleans, La., on April 29. However, the decline from the primary crest was slight, and after a few days another rise to still greater heights set in, and at the end of May it was still in progress below the mouth of the Arkansas River. Discussion of this lower Mississippi flood will therefore be postponed, as probably it will be about the middle of June when the crest of the flood passes into the Gulf of Mexico.

Mississippi River above the mouth of the Ohio.—The river did not reach the flood stage above Muscatine, Iowa, although it was quite high during late March and in April as far north as the mouth of the Wisconsin River. Comparatively little of the abnormally heavy winter snowfall over Wisconsin, Minnesota, and Iowa had melted by the end of February, but above normal temperatures during the first week of March started snow melting, although not in large quantity during the first week, and soon the main river and all tributary streams began to rise. While rains were neither frequent nor heavy, comparatively high temperatures continued, and by the middle of the third week of March little snow remained, and tributary streams generally were in flood, especially those of the State of Iowa, two of which, the Cedar and Nishnabotna Rivers, rose to the highest stages of record. During the early days of the flood the situation was further complicated by the occurrence of ice gorges, mainly over the southern portion of the State, that caused local overflows which were very destructive to bridges, highways, and farm property. For an excellent résumé of the conditions in the State of Iowa the reader is referred to the Monthly Climatological Summary of that State for the month of March.

The lower Wisconsin River flood was an April flood, beginning with the 7th at Merrill, and ending with the 13th at Portage, Wis. Warnings were issued at the proper time and there was no damage of consequence. Similar conditions prevailed during the first week of April in the lower Rock River of Illinois.

The upper Mississippi River was in flood from Muscatine, Iowa, to the mouth of the Ohio River, especially above St. Louis, Mo., the region of maximum intensity extending from the mouth of the Des Moines to the mouth of the Missouri River. At Muscatine the river was above the flood stage from March 19 to April 7, and again from April 13 to 25; at Keokuk, Iowa, continuously for 49 days from March 16 to May 3; at Warsaw, Ill., for 48 days from March 16 to May 2; at Quincy, Ill., for 55 days from March 14 to May 8; and at Hannibal and Louisiana, Mo., for 58 days from March 14 to May 11. From Keokuk to Louisiana the crest stages were but little below the highest recorded stages, and the flood was the greatest since June, 1903.

Reported loss and damage amounted to $1,185,500, divided as follows: Tangible property, $109,000; matured crops, $25,000; prospective crops (38,000 acres), $784,000; livestock, etc., $1,000; suspension of business, $266,000. Reported money value of property saved through flood warnings, $125,000.

On March 21 a crevasse occurred in the Indian Grave Levee, just north of Quincy, Ill., and 17,000 acres of land, much of it under cultivation, were overflowed. At about the same time a breach occurred in a small protecting levee at Canton, Mo., and a considerable portion of the lower section of the town was flooded. On April 21 the Marion County, Mo., levee along Fabius River broke, and 4,000 acres of land were overflowed. This levee also broke in November, 1928. On April 21 there was a further breach at Canton, Mo., and again the lower section of the town was inundated. The final crevasse was

that of April 24 in the South Quincy, Ill., Drainage District, and some 6,000 acres of rich agricultural lands, known as "Quincy Gardens," were flooded.

Not much farm work can be done during the month of May. Low places are full of water, there is much seep water, wheat plants are turning yellow at the base, and in the famous Sny Levee district not much more than a half crop is anticipated.

Warnings for all floods were timely and very accurate, and there were no preventable losses reported.

In the St. Louis section of the Mississippi River from below Louisiana, Mo., to above Cape Girardeau, Mo., the river was generally in flood a large part of the month, and during the entire month at Grafton and Alton, Ill.

Damage to wheat was great, and as two floods followed in May, there is much apprehension as to the possibility of being able to plant corn in time to enable it to reach maturity.

A general rise began in the Illinois River during the last week of February, and by March 1 all of the alluvial river, except the extreme lower reach, was in flood, and at the end of April the river was still in flood.

There were also floods in the Missouri River and tributaries east of Kansas City, but nothing of special consequence developed along the main stream. The Grand River was rather high during the first half of March and the last decade of April. There was also a flood in the Osage River, and it will be treated later in connection with a more decided May flood.

Warnings for these floods were of the usual accurate character, and received high commendation, as did others, from the press and others interested.

Reported loss and damage for March were as follows: Tangible property, $90,000; matured crops, $1,000; prospective crops, 15,000 acres, $150,000; total, $241,000. Reported value of property saved through flood warnings, $53,000.

Ohio Basin.—The Ohio River was not in flood during April above Dam No. 50, Fords Ferry, Ky., 104 miles above the mouth of the river, and at Cairo the crest stage was 51.5 feet, 6.5 feet above the flood stage, on April 5 and 6. The river fell below the flood stage on April 21, but after reaching 42.4 feet on April 25, it again began to rise under the influence of the upper Mississippi flood, and on the last day of the month the stage was 45.5 feet. Reports of loss and damage must be deferred until after the subsidence of the greater flood of May.

A series of moderate to heavy rains, beginning with April 7 caused quite general although not very damaging floods over the greater portion of the Wabash-White system of Indiana. Warnings were issued as required, and the reported damage amounted to only $21,000, $4,100 in tangible property, $7,700 in prospective crops, and $9,200 on account of suspension of business. The reported value of property saved through the warnings was $12,500.

Atlantic drainage.—New England rains were quite abundant during April, with also some melting of snow, and there were several marked rises in the rivers, with some damage along smaller streams, caused largely by the breaking of a few small dams. There were no flood stages reached in the Connecticut River except at Hartford, Conn., where the river was above the flood stage of 16 feet from April 22 to 24, inclusive, with a crest of 17.9 feet on April 23. Warnings were issued, and there was very little damage, although lowlands in Massachusetts and Connecticut were under water for some time. Moderate floods in the Hudson River between Troy and Castleton, N. Y., were also without incidents of interest.

In the basin of the North Branch of the Susquehanna River conditions were somewhat more marked and there were general floods with crest stages from 2 to 6.5 feet above the flood stages, the greatest excess occurring in the State of Pennsylvania. Damage was comparatively small, about $45,000 in all, not including damage caused by overflow of small streams.

There was a moderate flood in the Potomac River between April 16 and 18. The flood stage of 8 feet at Cumberland, Md., was exceeded by 1 foot on April 16, and at Harpers Ferry, W. Va., there was a crest of 21.3 feet, 3.3 feet above the flood stage, on April 17. At Washington, D. C., the crest stage of 8.1 feet on April 18 was 0.1 foot above the flood stage.

There was some overflow from the mouth of the Great Cacapon River to Harpers Ferry, resulting in considerable inconvenience and some interruption of traffic, but the actual losses were small.

Local floods in Virginia and the two Carolinas were not of importance. They were well forecast and damage was inconsequential.

Great Lakes drainage.—On April 1 a considerable quantity of rain and snow fell over lower Michigan, followed during the succeeding four days by heavy rains and high termperatures. Soon all rivers were rising rapidly, and over the drainage area of the Saginaw River there were quite important floods from April 6 to 10, inclusive.

The Saginaw River and its four important tributaries, the Tittabawassee, Chippewa, Cass, and Flint Rivers were in flood, and at Saginaw the Saginaw River on April 9 and 10 reached a stage of 21.4 feet, 2.4 feet above the flood stage.

Much damage was done in the city of Midland on the Tittabawassee River, and at Vassar on the Cass River. Lowlands and basements were flooded, roads washed out and thousands of acres of planted farm land overflowed. Not much damage was done in the city of Saginaw.

Total loss and damage as reported, amounted to $171,000, of which $100,000 was in tangible property, $36,000 in prospective crops, and $35,000 in suspension of business. The reported value of property saved at Midland and Vassar through the warnings was $46,000.

Miscellaneous.—The Arkansas River was generally in moderate flood from Webbers Falls, Okla., to Morrilton, Ark., between April 22 and 27, and there were two other less important rises earlier in the month.

Some crops in bottom lands were destroyed and planting was delayed, but on the whole losses were small. Similar conditions prevailed in the White River basin of Arkansas.

The rivers of eastern Kansas were in moderate flood on April 20 and 21, and a day or two later the floods extended throughout the Neosho River in Oklahoma.

Damage in the State of Kansas, as reported, amounted to $326,600, divided as follows: Tangible property, $93,600; matured crops, $10,000; prospective crops, $145,000; livestock and other movable property, $30,000; and suspension of business, $48,000. As frequently happens the major portion of the damage was caused by overflows of small streams, and growing crops suffered most. Savings reported as a result of the warnings amounted to $105,000

The Neosho and Arkansas River floods in the State of Oklahoma were three in number, each caused by a

single heavy rain of 24 hours' duration or less. The third flood, between April 20 and 26, with crests from 4 to 6 feet above flood stage was the only important one. However, owing to the operation of 15 sand and gravel companies in these districts, forecasts and warnings were equally necessary for the two previous rises. The value of the individual equipment of these companies ranges between $250,000 and $500,000, and failure to receive notice of decided rises means damage and loss to the equipment.

There was very little loss of livestock and other movable property during the flood, but 25,000 acres of land were overflowed causing a loss of $150,000 in prospective crops. Tangible property losses were $30,000, and those due to suspension of business, $7,500, a total of $187,500. Value of property saved through warnings, $30,000 plus the speculative amounts saved by the sand and gravel companies.

The floods in the Yazoo River will be covered in the report on the Lower Mississippi floods when published.

A few local floods in the Southwest were of minor character.

[All dates in April unless otherwise specified]

River and station	Flood stage	Above flood stages—dates		Crest	
		From—	To—	Stage	Date
ATLANTIC DRAINAGE					
	Feet			*Feet*	
Connecticut: Hartford, Conn	16	22	24	17.9	23.
		27	(1)		
Hudson:					
Troy, N. Y	15	22	22	17.2	22.
Albany, N. Y	12	22	22	12.8	22.
Hoosic: Hoosick Falls, N. Y	4	26	26	4.0	26.
Susquehanna:					
Oneonta, N. Y	12	13	14	13.0	13.
			27	15.7	22.
Bainbridge, N. Y	11	17	17	12.0	17.
		21	24	14.9	22.
Binghamton, N. Y	14	22	23	15.9	22.
Towanda, Pa	16	22	23	19.9	22.
Wilkes-Barre, Pa	20	21	24	26.5	22.
Chenango: Sherburne, N. Y	8	21	23	9.3	21.
Chemung: Corning, N. Y	16	21	21	16.4	21.
Potomac:					
Cumberland, Md	8	16	16	9.0	16.
Harpers Ferry, W. Va	18	17	18	21.3	17.
Washington, D. C	8	18	18	8.1	18.
James:					
Columbia, Va	18	17	18	22.4	17.
Richmond, Va	10	17	18	11.4	18.
Roanoke:					
Randolph, Va	21	17	17	21.3	17.
Weldon, N. C	30	18	20	37.2	18.
Neuse: Smithfield, N. C	14	19	19	14.5	19.
Cape Fear: Elizabethtown, N. C	22	18	19	23.0	18.
Peedee: Mars Bluff, S. C	17	(2)	6	25.4	Mar. 5.
		19	21	17.8	20.
Santee:					
Rimini, S. C	12	(2)	10	25.3	Mar. 9.
		14	(1)		
Ferguson, S. C	12	(2)	(1)	17.5	Mar. 10.
Saluda:					
Pelzer, S. C	7	29	29	7.2	29.
Chappells, S. C	14	30	(1)		
Altamaha:					
Charlotte, Ga	15	(2)	7	26.7	Mar. 6.
Everett City, Ga	10	(2)	11	16.0	Mar. 15–16.
Ocmulgee: Abbeville, Ga	11	(2)	2	19.6	Mar. 10.
EAST GULF DRAINAGE					
Apalachicola: Blountstown, Fla	20	(2)	3	28.6	Mar. 21.
Alabama: Selma, Ala	35	(2)	1	56.2	Mar. 19.
Tombigbee: Lock 4, Demopolis, Ala	39	(2)	9	65.5	Mar. 28.
Pearl:					
Jackson, Miss	20	(2)	7	32.2	Mar. 24, 25, 28, 29.
		28	(1)	20.6	Apr. 29–30.
Monticello, Miss	18	(2)	6	20.6	Mar. 28–31.
Columbia, Miss	18	(2)	9	21.9	2.
West Pearl: Pearl River, La	13	(2)	16	15.4	6–8.
GREAT LAKES DRAINAGE					
St. Joseph: Montpelier, Ohio	10	2	2	10.6	2.
		22	24	13.8	22.
Saginaw: Saginaw, Mich	19	6	15	22.4	9–10.
Flint: Flint, Mich	11	7	9	12.3	8.
GREAT LAKES DRAINAGE—cont.					
Tittabawassee:	*Feet*			*Feet*	
Midland, Mich	18	6	10	21.4	8.
Shields, Mich	16	6	11	18.4	9.
Chippewa: Mount Pleasant, Mich	12	8	9	12.6	9.
Cass: Vassar, Mich	14	2	2	14.7	2.
		5	9	18.5	6.
Grand:					
Eaton Rapids, Mich	5	1	10	5.5	3.
		21	30	5.2	23.
Grand Ledge, Mich	7	1	5	7.0	1–5.
		22	23	7.0	22–23.
Red Cedar: East Lansing, Mich	8	22	22	8.0	22.
MISSISSIPPI DRAINAGE					
Ohio:					
Dam No. 50, Fords Ferry, Ky	35	1	2	35.4	1.
Paducah, Ky	43	1	6	43.8	3.
Dam No. 52, Brookport, Ill	43	1	6	44.0	3.
Dam No. 53, Grand Chain, Ill	43	(2)	11	48.7	Mar. 19–20.
		15	17	43.1	16–17.
Cairo, Ill	45	(2)	21	51.9	Mar. 20.
		29	(1)		
Shenango: Sharon, Pa	9	5	7	11.9	5.
Beaver: Beaver Falls, Pa	11	5	6	12.3	5.
Scioto:					
Larue, Ohio	11	11	11	11.0	11.
Circleville, Ohio	10	11	11	11.0	11.
Walhonding: Walhonding, Ohio	8	22	22	8.8	22.
Wabash:					
Lafayette, Ind	13	2	4	16.7	3.
		12	12	13.2	12.
Covington, Ind	16	2	5	19.8	4.
		12	14	17.3	13.
Terre Haute, Ind	16	11	11	16.1	11.
Vincennes, Ind	14	11	18	16.3	15.
Mount Carmel, Ill	16	11	20	21.0	17.
White: Decker, Ind	18	15	18	19.6	17.
White, East Fork: Seymour, Ind	10	12	12	10.5	12.
White, West Fork:					
Elliston, Ind	19	11	14	22.4	13.
Edwardsport, Ind	15	11	16	18.1	14.
Cumberland:					
Carthage, Tenn	40	(2)	1	55.6	Mar. 25.
Nashville, Tenn	40	(2)	4	50.9	Mar. 30–31.
Clarksville, Tenn	46	(2)	6	54.4	1.
Lock F, Eddyville, Ky	57	(2)	8	62.5	4.
Tennessee:					
Florence, Ala	18	(2)	1	22.8	Mar. 25.
Riverton, Ala	33	(2)	3	44.6	Mar. 25–26.
Savannah, Tenn	40	(2)	4	44.5	Mar. 27.
Johnsonville, Tenn	31	(2)	6	36.8	Mar. 29.
Mississippi:					
Muscatine, Iowa	16	(2)	7	16.7	Mar. 23.
		13	25	17.0	Apr. 21.
Keokuk, Iowa	14	(2)	May 3	19.4	Mar. 23.
Warsaw, Ill	17	(2)	May 2	22.0	Mar. 23.
Quincy, Ill	14	(2)	May 8	21.4	23, 27.
Hannibal, Mo	13	(2)	May 11	22.1	27.
Louisiana, Mo	12	(2)	May 11	21.1	27.
Grafton, Ill	18	(2)	(1)	26.2	28.
Alton, Ill	21	(2)	(1)	30.1	28.
St. Louis, Mo	30	12	13	30.5	12.
		24	(1)	34.6	27–28.
Chester, Ill	27	4	18	30.0	13.
		24	(1)	33.3	28.
Cape Girardeau, Mo	30	(2)	(1)	36.9	29, 30.
New Madrid, Mo	34	(2)	(1)	41.0	Mar. 21.
Memphis, Tenn	35	(2)	(1)	41.1	11.
Helena, Ark	44	(2)	(1)	41.2	13.
Arkansas City, Ark	48	(2)	(1)	55.5	17–22.
Greenville, Miss	42	(2)	(1)	49.3	21–23.
Vicksburg, Miss	45	(2)	(1)	52.7	25, 26, 29, 30.
Natchez, Miss	46	(2)	(1)	52.1	27–30.
Angola, La	45	(2)	(1)		
Baton Rouge, La	35	(2)	(1)		
Donaldsonville, La	28	2	(1)		
New Orleans, La	17	8	(1)		
Wisconsin:					
Merrill, Wis	11	7	8	11.6	7.
Knowlton, Wis	12	6	10	16.0	8.
Portage, Wis	17	11	13	17.9	12.
Rock: Moline Bridge, Ill	11	(2)	7	13.4	Mar. 20.
		22	29	11.9	25.
Des Moines: Ottumwa, Iowa	10	26	26	10.0	26.
Salt: New London, Mo	20	26	26	21.5	26.
Illinois:					
Morris, Ill	13	1	4	15.3	2.
		11	13	14.6	12.
Peru, Ill	14	(2)	(1)	21.2	Mar. 18–19.
				20.3	Apr. 2, 3.
Henry, Ill	10	(2)	(1)	16.0	Mar. 20–21.
				15.4	Apr. 4.
Peoria, Ill	18	(2)	(1)	22.5	Mar. 20–22.
				21.8	Apr. 5, 6, 9.
Havana, Ill	14	(2)	(1)	19.6	6.
Beardstown, Ill	14	(2)	(1)	21.2	6.
Pearl, Ill	12	(2)	(1)	19.7	6–7.
				21.3	29–30.

[1] Continued at end of month.

[2] Continued from last month.

River and station	Flood stage	Above flood stages—dates From—	To—	Crest Stage	Date
MISSISSIPPI DRAINAGE—continued					
Meramec:	*Feet*			*Feet*	
Pacific, Mo.	11	9	12	15.1	12.
Valley Park, Mo.	14	10	12	18.0	12.
Missouri:					
Waverly, Mo.	23	22	23	24.0	23.
Boonville, Mo.	21	24	26	22.8	25.
Hermann, Mo.	21	24	27	22.8	26.
St. Charles, Mo.	25	11	14	26.6	11.
		23	29	30.5	26.
Kansas: Topeka, Kans.	21	20	20	21.8	20.
Solomon: Beloit, Kans.	18	20	21	22.2	21.
Grand:					
Gallatin, Mo.	20	20	23	33.5	21.
Chillicothe, Mo.	18	20	27	30.2	22.
Brunswick, Mo.	12	22	28	18.5	24.
Grand, Thompsons Fork: Trenton, Mo.	20	20	20	21.4	20.
Osage:					
Osceola, Mo.	20	9	12	23.5	11.
		21	30	22.0	22.
Warsaw, Mo.	22	9	13	26.0	10.
Tuscumbia, Mo.	25	10	14	28.5	12.
Arkansas:					
Webbers Falls, Okla.	23	16	16	23.8	16.
		22	25	26.1	23.
Fort Smith, Ark.	22	17	17	22.7	17.
		22	26	25.2	24.
Dardanelle, Ark.	20	18	18	20.6	18.
		24	27	23.0	25.
Morrilton, Ark.	20	24	27	22.2	27.
Yancopin, Ark.	29	(2)	(1)	41.4	20–22.
Neosho:					
Oswego, Kans.	17	20	23	23.0	21.
		26	26	19.1	26.
Wyandotte, Okla.	23	21	22	26.8	22.
Pensacola, Okla.	24	19	25	28.2	19.
Fort Gibson, Okla.	22	10	10	22.3	10.
		15	16	23.0	16.
		21	26	28.3	23.
Verdigris:					
Independence, Kans.	30	20	23	41.9	21.
		25	25	34.3	25.
Sageeyah, Okla.	35	22	28	40.4	26.
Petit Jean: Danville, Ark.	20	9	11	21.1	10.
White:					
Calico Rock, Ark.	18	9	12	22.1	10.
Batesville, Ark.	23	9	13	28.8	11.
Newport, Ark.	26	11	25	29.3	13.
Georgetown, Ark.	22	13	(1)	25.8	22.
DeValls Bluff, Ark.	24	16	(1)	26.2	22, 23, 25, 26.
Clarendon, Ark.	30	20	(1)	30.7	25–27.
Black:					
Williamsville, Mo.	11	10	10	11.6	10.
Poplar Bluff, Mo.	14	10	12	15.9	11.
		17	17	14.9	17.
Corning, Ark.	11	4	(1)	13.7	16,17.
Black Rock, Ark.	14	5	(1)	22.7	11.
Cache: Patterson, Ark.	9	14	25	9.5	16,17.
Yazoo: Yazoo City, Miss.	25	(2)	(1)	29.6	26–29.
Tallahatchie: Swan Lake, Miss.	25	(2)	(1)	31.7	Mar. 29–Apr. 1.
Atahafalaya:					
Simmesport, La.	41	13	(1)		
Melville, La.	37	Mar. 28	(1)		
WEST GULF DRAINAGE					
Trinty: Dallas, Tex.	25	21	21	25.9	21.
Brazos: Freeport, Tex.	4	13	13	4.1	13.
Guadalupe: Victoria, Tex.	16	10	13	22.8	13.
Rio Grande: San Marcial, N. Mex.	3	8	8	3.0	8.
PACIFIC DRAINAGE					
Colorado: Parker, Ariz.	7	8	16	8.1	11.
		22	(1)	8.6	27.
Salt: Phoenix, Ariz.	5	5	6	6.7	5.

[1] Continued at end of month. [2] Continued from last month.

THE EFFECT OF WEATHER ON CROPS AND FARMING OPERATIONS, APRIL, 1929

By J. B. KINCER

General summary.—During the first decade vegetation of all kinds made exceptional progress, with abnormally warm weather and mostly ample soil moisture in Central and Eastern States. Fruits advanced unfavorably, with early varieties in bloom as far north as northern Indiana and southern Iowa, or two or three weeks earlier than the average. Field work made good progress in most areas, but rain or wet soil caused further interruption in some interior sections, although spring planting advanced better than during the previous month. Local storms and tornadoes did some damage in Central-Northern States.

During the second decade rather frequent rains and wet soil in the interior caused further delay to spring work, with the progress in preparations two to three weeks late in sections; some plowing and seeding were accomplished locally. The unfavorable advance of fruit trees resulted in considerable harm in many places as heavy to killing frosts occurred during the period; much local injury was reported in the Appalachian region, but elsewhere only light harm resulted. In the South the weather permitted active field operations, and the previous rains greatly benefited the crops of Florida, but parts of Texas and New Mexico were still dry. Cold rain or snow was detrimental to livestock in some western sections, especially to young lambs; rain was needed in parts of the Pacific Northwest.

During the last decade frequent rainfall and continued wet soil caused further delay to spring work in many important agricultural sections, and dry, warm weather was needed generally from the central and northern Atlantic area westward to the Great Plains. Field work was delayed also in the southeast and north-central Cotton Belt, but seasonal preparations made satisfactory advance elsewhere in the South; rain was still needed in the Southwest, especially in western Texas and Oklahoma. Conditions were largely favorable in the Great Plains, especially in the North where spring work advanced rapidly.

Small grains.—Winter wheat made very good advance during the first decade in the central and eastern portions of the belt, except for some reports of wet soil. There was some soil blowing in parts of Kansas and Nebraska, but the crop did well in most of the Plains States; the Pacific Northwest still needed rain, but rapid growth was made elsewhere. Conditions were rather unfavorable for best growth of winter wheat in the Ohio Valley during the second decade, with some yellowing, and growth varied widely in the trans-Mississippi States, ranging from poor to excellent. Growth was very good in the Great Plains with the plants jointing in eastern Kansas. Marked improvement was made in Washington and some advance in Oregon; favorable conditions prevailed elsewhere, except for the dry portions of Texas. During the last decade growth of winter wheat varied greatly in the eastern belt, but condition remained mostly unchanged, except for some additional reports of yellowing in the interior valleys. The crop did well in the Great Plains, with much jointing in southern and eastern Kansas, but rain was still badly needed in parts of the Southwest.

Seeding spring wheat made good advance in most sections of the belt, except for some delay by wet soil in North Dakota, but toward the close of the month drying winds permitted resumption of work in the previously wet areas. Much wheat was still unsown in South Dakota at the close, but the early crop was coming up nicely to good stands and color. Oat seeding was well along during the first decade, but the weather during the latter part of the month was unfavorable for this work and at the close some rather widespread areas were still to be seeded; the winter crop did well generally.

Corn.—Preparations for corn planting were rather active during the first decade in much of the interior and eastern sections, but the soil continued too wet in considerable portions of the upper Mississippi Valley, es-

pecially in Iowa. Preparation of seed beds and planting made slow progress during the second decade, due to wet soil. Very little work was possible in Iowa and Missouri, but seeding made good advance in the Great Plains, except in some eastern parts. Continued unfavorable weather further delayed corn planting in the main parts of the belt the last part of the month, with some sections reporting this work two to three weeks late. In the Southwest and most of the Great Plains planting was favored while in the South conditions were rather favorable, though warmer weather was needed.

Cotton.—Much preparation of soil was possible in the Cotton Belt during the first decade, except for some locally wet sections. Some cotton was planted as far north as extreme southern North Carolina to central Arkansas and locally to southeastern Oklahoma. Seeding made rapid progress in Georgia, was general in South Carolina, and in the west to west-central Texas. During the second decade the nights were rather too cool for best germination in the eastern belt, but planting made mostly satisfactory advance. Early plantings were completed in South Carolina, with some cultivation, and seeding progressed rapidly in Georgia with some fields ready to chop out in southern parts. Planting progressed in parts of Arkansas and Oklahoma, and in Texas growth and stands were mostly good with general condition fairly good to excellent.

During the last decade temperatures were mostly seasonable, although the nights were rather too cool for good germination in many sections. Planting progressed well in more eastern parts, but elsewhere east of the Mississippi River frequent rains caused some delay, with many irregular stands reported. It was too cool and wet in much of Arkansas, but good progress was made in Oklahoma under favorable conditions. In Texas the weather favored planting, replanting, and chopping, and progress of the early-planted crop was good, with stands and general condition mostly satisfactory.

Miscellaneous crops.—Meadows and pastures did well in practically all sections east of the Mississippi River and ranges were generally satisfactory in the Great Plains. Some livestock were on range in Montana, but growth of grass was mostly slow; conditions were generally favorable in Wyoming until near the close, but the severe weather then prevailing was of short duration and losses were light. Satisfactory conditions prevailed elsewhere, except for some slow growth of grass, due to cool weather, in the Great Basin. Livestock did well generally, but there were continued reports of local losses to shorn sheep and young lambs.

Potato planting progressed during the month, and at the close had begun north to the northern border States. Truck crops did well, except for some frost injury to tender varieties during the second decade. The unfavorable forcing of fruit which continued into the first decade resulted in rather widespread harm from the frosts of the second decade in the northern parts of the country, extending southward into the Appalachian region. Citrus needed rain in Florida, and toward the close of the month there were reports of fruit dropping; satisfactory condition was indicated in California.

WEATHER OF THE ATLANTIC AND PACIFIC OCEANS

NORTH ATLANTIC OCEAN

By F. A. YOUNG

Over the greater part of the ocean the weather conditions during April would not be considered unusual, although the number of days with gales was above the normal along the American coast between Hatteras and Nova Scotia and also over a limited area in the middle section of the steamer lanes.

As shown in Table 1, the average pressure at three land stations on the British Isles was above normal, but the positive departures were not as large as in March. The North Atlantic HIGH, while somewhat more active than in the previous month, was still less prominent than usual, and in consequence, at times easterly winds replaced the usual westerlies over the eastern section of the steamer lanes.

Fog was unusually prevalent over the Grand Banks and off the American coast north of the thirty-fifth parallel; it was reported on from 2 to 3 days in the vicinity of the British Isles, 1 day in the Gulf of Mexico, and not over 1 day in any 5° square on the steamer lanes between the twentieth and fortieth meridians.

On the 2d a LOW central near Sydney, Nova Scotia, was responsible for moderate westerly gales in the southerly quadrants, that continued until the 3d, although on the latter date the storm area had contracted somewhat in extent.

On the 6th a LOW was over the Straits of Belle Isle that moved rapidly eastward, and on the 7th moderate to strong gales accompanied by rain and hail prevailed over the steamer lanes between the thirtieth and forty-fifth meridians. From the 8th to 10th moderate weather was the rule, although a few vessels encountered winds of force 7 and 8 in different sections of the steamer lanes.

TABLE 1.—*Averages, departures, and extremes of atmospheric pressure at sea level, 8 a. m. (seventy-fifth meridian). North Atlantic Ocean, April, 1929*

Stations	Average pressure	Departure	Highest	Date	Lowest	Date
	Inches	*Inch*	*Inches*		*Inches*	
Julianehaab, Greenland	[1] 29.80	([2])	30.38	18th	29.08	11th.
Belle Isle, Newfoundland	29.84	[3] +0.01	30.30	4th [4]	28.80	25th.
Halifax, Nova Scotia	29.94	[3] +0.01	30.48	12th	29.32	18th.
Nantucket	29.89	[3] −0.08	30.36	3d	28.94	17th.
Hatteras	29.99	[3] −0.04	30.50	3d	29.14	16th.
Key West	30.02	[3] +0.01	30.26	3d [4]	29.72	16th.
New Orleans	29.99	[3] −0.05	30.32	4th	29.64	15th.
Cape Gracias, Nicaragua	29.91	[3] −0.06	29.98	4th	29.82	10th. [4]
Turks Island	30.09	[3] +0.07	30.24	3d [4]	29.90	16th. [4]
Bermuda	30.17	[3] +0.09	30.46	4th	29.70	17th.
Horta, Azores	30.03	[3] −0.08	30.46	29th	29.66	9th.
Lerwick, Shetland Islands	29.96	[3] +0.16	30.53	11th	29.57	27th.
Valencia, Ireland	30.04	[3] +0.15	30.29	11th	29.47	28th.
London	29.99	[3] +0.12	30.34	17th	29.43	29th.

[1] Average of 26 observations.
[2] No normal available.
[3] From normals shown on Hydrographic Office Pilot Chart, based on observations at Greenwich mean noon, or 7 a. m., seventy-fifth meridian time.
[4] And on other date or dates.
[5] From normals based on 8 a. m. observations.

Charts VIII to XI show the conditions from the 11th to 14th, inclusive, when one disturbance prevailed over the middle and eastern sections of the ocean, and another off the American coast.

At the time of morning observation on the 15th the land station at Vera Cruz, Mexico, reported a barometer of 29.74 inches, wind north, force 8, with a maximum velocity of 64 miles an hour. No reports have been received from vessels in this vicinity or in any port of the Gulf of Mexico denoting any but moderate winds on that day, although an area of low pressure was over Alabama and Northern Florida with barometric readings of 29.56

and 29.58 inches at Pensacola and Jacksonville, respectively.

On the 16th the center of this LOW was between New York and Nantucket and winds of hurricane force were encountered by vessels near the center, while the station at Atlantic City reported a northeast wind of 75 miles an hour, barometer, 29.10 inches. This disturbance moved but little during the next 48 hours, and decreased somewhat in intensity, although on the 17th westerly to southwesterly gales still prevailed between the Bermudas and Nova Scotia, and on the 18th between Hatteras and New York.

On the 18th a disturbance was over the Azores that increased in intensity as it moved northeastward, and on the 19th moderate to strong gales were over the eastern section of the southern steamer lanes, while on the 20th the storm area extended as far north as the fiftieth parallel.

On the 22d a moderate depression was central about 200 miles east of Nantucket and a second LOW of somewhat greater intensity near 47° N., 35° W., while northwesterly gales occurred over the middle section of the steamer lanes. On the 23d the western LOW was central near Sable Island and on the 24th near Belle Isle. On both dates moderate gales prevailed between the fortieth and fiftieth parallels.

On the 26th the Province of Quebec was covered by an area of low pressure, and strong southwesterly gales were encountered along the American coast between Halifax and Jacksonville.

On the 27th a shallow depression was over the eastern section of the steamer lanes, that deepened as it moved eastward, and on the 28th moderate to strong northerly gales occurred over a limited area between the forty-fifth and fifty-fifth parallels, east of the tenth meridian. By the 29th the center of this LOW was near the English Channel and favorable conditions were the rule, except for moderate northerly gales between the forty-ninth and fifty-fifth parallels and the tenth and fifteenth meridians.

On the 29th Portland, Me., was near the center of a LOW that moved slowly northward and on the 30th was near Father Point, Quebec; moderate conditions prevailed on both days.

OCEAN GALES AND STORMS, APRIL, 1929

Vessel	Voyage		Position at time of lowest barometer		Gale began	Time of lowest barometer	Gale ended	Lowest barometer	Direction of wind when gale began	Direction and force of wind at time of lowest barometer	Direction of wind when gale ended	Highest force of wind and direction	Shifts of wind near time of lowest barometer
	From—	To—	Latitude	Longitude									
NORTH ATLANTIC OCEAN			° ′	° ′				*Inches*					
President Polk, Am. S. S.	Marseille	New York	40 37 N	69 37 W	Apr. 1	10 p, 1	Apr. 2	29.61	S	S, 6	WNW	WNW, 10	S-SW-WNW.
Exton, Am. S. S.	Alexandria	Boston	42 54 N	60 54 W	2	4 a, 2	2	29.65	SW	SW, 7	NW	W, 9	SW-W.
D. G. Scofield, Am. S. S.	New York	Colombia	38 31 N	73 49 W	4	4 a, 4	5	30.21	S	S, 4	SW	SW, 10	S-SW.
St. Dunstan, Br. S. S.	River Tyne	Galveston	41 08 N	37 49 W	6	Mdt, 6	7	29.50	S	S, 9	N	S, 9	S-W-N.
Schenectady, Am. S. S.	Gothenburg	Portland, Me.	48 03 N	42 05 W	7	1 a, 7	7	29.29	WNW	SW, 6	NW	WNW, 11	SW-NW.
Lepanto, Br. S. S.	Newcastle	New York	45 57 N	34 30 W	6	11 a, 7	7	29.53	SSE	SSE, 10	WNW	SSE, 10	SSE-W-WNW.
Georgie, Fr. S. S.	Antwerp	Guadeloupe	33 37 N	35 05 W	8	6 p, 8	8	29.46	SSW	S, 10	W	S, 10	S-W.
Barendrecht, Du. S. S.	Lisbon	Philadelphia	34 58 N	31 20 W	8	1 a, 9	9	29.22	S	S, —	WSW	S, 9	S-WSW.
Winnebago, Br. S. S.	Manchester	Bayonne, N.J.	48 53 N	31 44 W	9	4 a, 10	10	28.85	SE	WSW, 12	W	WSW, 12	SE-WSW.
New York, Ger. S. S.	Cuxhaven	New York	44 23 N	39 34 W	10	2 a, 11	11	28.96	SE	NNW, 12	NW	NNW, 12	SSW-NNW.
Berlin, Ger. S. S.	Bremen	do	40 38 N	68 26 W	12	4 p, 12	13	29.67	E	E, 8	N	E, 10	E-N.
West Zeda, Am. S. S.	Aberdeen	Gulfport	52 08 N	29 52 W	11	10 p, 12	12	28.85	SE	SE, 11	S	SE, 11	SE-S.
Mercier, Belg. S. S.	New York	Antwerp	40 20 N	64 56 W	13	—, 13	14	29.68	E	E, 11	NNW	E, 11	
Leviathan, Am. S. S.	do	Southampton	41 25 N	40 06 W	12	8 p, 13	13	29.70	NW	WNW, 8	WNW	NW, 10	NW-WNW.
Duivendrecht, Du. M. S.	New Orleans	Lands End	48 45 N	15 00 W	11	11 a, 13	13	29.60	SE	SSE, 9	SW	SSE, 9	SSE-SW.
Grootendijk, Du. S. S.	Canal Zone	Hamburg	49 40 N	6 50 W	11	4 p, 14	14	29.59	SSE	SSE, 8	SSW	SSE, 9	SSE-SSW.
West Madaket, Am. S. S.	Liverpool	Mobile	46 12 N	18 29 W	13	9 a, 14	15	29.35	S	W, 9	W	—, 10	S-SW-W.
Reliance, Ger. S. S.	New York	Hamburg	40 05 N	72 09 W	16	Noon, 16	16	29.04	NE	E, 10	E	ENE, 12	ENE-E.
Gulfprince, Am. S. S.	Beverly, Mass.	Port Arthur	40 00 N	70 00 W	16	Noon, 17	19	28.90	E	S, 7	NW	E, 10	
Exarch, Am. S. S.	Lisbon	New York	38 09 N	26 07 W	18	4 a, 18	19	29.68	N	W, 4	N	NNW, 10	N-NNW-N.
River Orontes, Br. S. S.	Gibraltar	do	36 28 N	25 30 W	19	—, 19	20	29.54	N	N, 9	N	N, 9	Steady.
Mississippi, Br. M. S.	New York	London	40 43 N	56 00 W	23	4 a, 23	24	29.43	W	W, 9	WNW	W, 10	W-WNW.
Rijndam, Du. S. S.	Rotterdam	New York	45 43 N	52 32 W	23	—, 24	24	28.79	SSE	SSW, 9	SW	SW, 10	S-WSW.
Yapalaga, Am. S. S.	Avonmouth	Savannah	32 30 N	77 08 W	25	4 p, 25	26	29.89	S	SSW, 9	WNW	SW, 9	SSW-WNW.
Tynefield, Br. M. S.	Liverpool	New York	41 00 N	65 38 W	25	8 a, 26	26	29.66	SW	SSW, 8	WSW	SSW, 10	SW-SSW.
Balsam, Am. S. S.	New York	Glasgow	52 09 N	22 59 W	27	8 a, 27	29	29.77	NNW	NNW, 7	NNE	N, 9	NNW-NNE.
NORTH PACIFIC OCEAN													
Dickenson, Am. S. S.	Midway Island.	Honolulu	24 30 N	164 15 W	2	1 a, 2	2	29.95	NNE	NNE, 7		N, 8	NNE-N.
Paris Maru, Jap. S. S.	Yokohama	Vancouver	48 30 N	175 15 E	5	10 a, 6	6	29.10	ENE	S, 8	SSW	NNE, 9	E-SE-S.
Golden Hind, Am. S. S.	San Francisco	Yokohama	31 57 N	174 42 E	7	1 a, 7	7	29.97	NE	NE, 5	NE	NE, 8	Steady.
President Wilson, Am. S. S.	Honolulu	Kobe	33 31 N	144 55 E	8	6 a, 8	8	29.79	S	S, 8	N	S, 8	S-SW.
Havre Maru, Jap. S. S.	Yokohama	San Francisco	47 03 N	154 11 W	13	4 a, 13	14	29.31	WNW	WNW, 5	W	WNW, 8	Steady.
Kurohime Maru, Jap. S. S.	Muroran	Vancouver	49 20 N	132 32 W	13	11 p, 13	14	29.00	S	S, 8	SSW	S, 9	S-SSW.
Makiki, Am. S. S.	Seattle	Honolulu	44 19 N	132 35 W	15	Noon, 15	15	29.34	S	SW, 8	W	SW, 9	SW-W.
Nevada, Am. S. S.	Portland	Shanghai	39 10 N	136 51 E	21	Noon, 22	22	28.73	ENE	N, 5	WNW	NW, 11	ENE-N.
Tamaha, Br. S. S.	San Pedro	Osaka	33 13 N	142 36 E	21	Noon, 21	23	29.19	SW	WSW, 8	WNW	W, 9	WSW-W.
President Van Buren, Am. S. S.	Honolulu	Kobe	33 37 N	150 52 E	22	2 p, 22	23	29.82	WSW	W, 8	NW	W, 9	WSW-W.
Winifred O'Donnell, Am. S. S.	Manila	Los Angeles	43 55 N	147 43 W	28	4 p, 28	28	29.68	SE	SE, 6	SE	SE, 8	SE-S.
Dalblair, Br. S. S.	Shanghai	Vancouver	50 07 N	153 15 W	28	Mdt, 28	29	29.68	E	E, 8	E	E, 8	ENE-E.
Yogen Maru, Jap. S. S.	Columbia	Yokohama	47 42 N	160 34 E	28	8 p, 29	30	29.50	S	S, 8	WSW	S, 8	5 pts.
SOUTH PACIFIC OCEAN													
James McGee, Am. S. S.	Buenos Aires	Talara	50 18 S	77 24 W	1	Noon, 2	2	28.43	NW	NNW, 12	SW	W, 12	Steady.
Clydefield, Br. M. S.	River Plate	California	50 45 S	77 25 W	26	2 a, 28	29	29.29	NNW	NNW	WSW	NNW, 10	Steady.

NORTH PACIFIC OCEAN

By WILLIS E. HURD

At the beginning of April there were few traces of cyclonic disturbances over any part of the North Pacific Ocean. The Aleutian region was overspread with an anticyclone of great magnitude, and in the Far East the barometer was mostly high, with no depressed areas of consequence. The only cyclone under observation was one of moderate strength lying between longitude 140° W. and the California coast. This disturbance merged on the 4th with the low pressure area then existent over the western part of the United States, after causing some isolated gales of force 8 at sea on the 3d.

Cyclonic conditions came into the Aleutian region on the 6th, but were mostly confined to the Bering Sea until the 11th, when a considerable depression crossed into the Gulf of Alaska, where it deepened into a cyclone with central pressures below 29 inches on the 12th and 13th. Following this the Aleutian cyclone redeveloped to the westward and continued with centers of fluctuating depth and position until the end of the month, its average center lying over the southwestern waters of the Gulf of Alaska, with neighboring pressures generally not far from normal.

The Pacific-California anticyclone was highly developed in middle latitudes throughout most of the month, and high pressures extended practically across the ocean, with few intruding LOWS.

Pressure data for several island and coast stations in west longitudes are given in the following table:

TABLE 1.—*Averages, departures, and extremes of atmospheric pressure at sea level at indicated hours, North Pacific Ocean and adjacent waters, April, 1929*

Stations	Average pressure	Departure from normal	Highest	Date	Lowest	Date
	Inches	*Inch*	*Inches*		*Inches*	
Point Barrow [1] [2]	29.93	-------	30.50	6th [6]	29.40	10th.
Dutch Harbor [1]	29.77	−0.06	30.66	1st	29.06	24th.
St. Paul [1]	29.84	+0.04	30.68	2d	29.26	23d. [6]
Kodiak [1]	29.78	−0.02	30.42	3d	29.02	13th.
Midway Island [1] [3]	30.21	+0.11	30.34	11th	30.00	1st.
Honolulu [4]	30.08	+0.01	30.16	26th	29.96	1st.
Juneau [4]	29.94	−0.02	30.42	4th	29.06	14th.
Tatoosh Island [4] [5]	29.97	−0.07	30.41	30th	29.30	14th.
San Francisco [4] [5]	30.06	+0.02	30.28	7th	29.80	18th.
San Diego [4] [5]	30.02	+0.06	30.16	14th	29.88	18th.

[1] P. m. observations only.
[2] For 27 days.
[3] For 28 days.
[4] A. m. and p. m. observations.
[5] Corrected to 24-hour mean.
[6] And on other dates.

April was a comparatively quiet month over the entire North Pacific, although more or less isolated and mostly fresh gales were reported along the upper routes on about 20 days. Very few high winds were met with in lower latitudes, and strong gales in any locality were rare, only one exceeding force 9 being encountered by an observing vessel. This was in the eastern part of the Japan Sea, where the American steamer *Nevada* was caught in a northwest gale of force 11 on the 21st. The storm in which this occurred was by far the most violent progressive cyclone of the month. It seems to have formed in a long trough of low pressure south of Japan on the 19th and to have moved north into the Japan Sea, where it intensified greatly on the 21st; thence it crossed the archipelago with strong gales on the 21st and 22d and proceeded seaward with lessening intensity. During these two days westerly gales of force 8–9 were encountered on the storm's lower quadrants from south of Yokohama eastward to a distance of a thousand or more miles at sea.

A moderate norther occurred in the Gulf of Tehuantepec on the 3d.

The prevailing wind direction at Honolulu was from the east, trades blowing there on all but one day. The maximum velocity was at the rate of 29 miles an hour from the east on the 11th.

Fog this month was observed from Lower California up the coast to Vancouver, thence westward along the upper steamship routes to Japan, and down to the Ogasawara Islands, near which it was reported on two days. Throughout the delineated area it occurred on from one to four days. This was the first month of the year to have consequential fog in east longitudes. There were two reports of fog off the Central American coast near 10° 45′ N., 89° W., on the 10th. That of the American tanker *New Jersey*, Capt. Edw. Jonassen, Homer Epps, observer, is given herewith:

Temperatures of air and water, 76°. Very heavy dew preceded fog, with upper sky clear, visibility poor, haze around the horizon. This gradually became worse until, from 4.13 to 5.28 a. m., the fog obliterated everything, visibility being confined to approximately 300 feet. Wind was light NNW. Fog backed in from SW., then light variable airs prevailed.

CLIMATOLOGICAL TABLES [1]

CONDENSED CLIMATOLOGICAL SUMMARY

In the following table are given for the various sections of the climatological service of the Weather Bureau the monthly average temperature and total rainfall; the stations reporting the highest and lowest temperatures, with dates of occurrence; the stations reporting the greatest and least total precipitation; and other data as indicated by the several headings.

The mean temperature for each section, the highest and lowest temperatures, the average precipitation, and the greatest and least monthly amounts are found by using all trustworthy records available.

The mean departures from normal temperatures and precipitation are based only on records from stations that have 10 or more years of observations. Of course, the number of such records is smaller than the total number of stations.

Condensed climatological summary of temperature and precipitation by sections, April, 1929

Section	Temperature								Precipitation					
	Section average	Departure from the normal	Monthly extremes						Section average	Departure from the normal	Greatest monthly		Least monthly	
			Station	Highest	Date	Station	Lowest	Date			Station	Amount	Station	Amount
	°F.	°F.		°F.			°F.		In.	In.		In.		In.
Alabama	66.8	+3.3	Fayette	95	[1] 5	Valley Head	35	16	4.64	+0.35	Lock No. 4	8.21	Troy (No. 2)	1.48
Arizona	57.6	−1.9	Parker	103	30	Bright Angel Ranger	−4	10	0.62	−0.02	Cordes	2.90	15 stations	0.00
Arkansas	64.0	+2.6	Prescott	92	8	Dutton	29	1	5.69	+0.81	Marshall	12.94	Amity	1.91
California	50.8	−4.4	Greenland Ranch	100	17	Helm Creek	−16	11	2.07	+0.36	Crescent City	13.49	3 stations	0.00
Colorado	42.4	−1.1	2 stations	90	4	Silverton	−12	10	1.61	−0.23	Peetz	7.13	2 stations	T.
Florida	73.0	+3.1	Venus	96	28	Moore Haven	42	18	3.40	+0.74	Apalachicola	8.23	Key West	0.40
Georgia	67.1	+3.7	Milledgeville	94	7	Clayton	29	18	4.02	+0.44	Dahlonaga	7.19	Lumber City	1.30
Idaho	41.7	−2.9	4 stations	80	[1] 16	Warren	−11	12	1.92	+0.45	Council	6.16	Bliss	0.28
Illinois	55.1	+2.7	Jacksonville	93	4	Freeport	23	1	5.23	+1.82	Carlinville	8.34	Cairo	2.97
Indiana	54.9	+2.9	Madison	89	6	Howe	21	19	5.04	+1.54	Howe	8.24	Greensburg	2.89
Iowa	51.2	+2.3	Little Sioux	93	4	Inwood	9	1	4.62	+1.66	Muscatine	7.97	Sioux Center	1.81
Kansas	56.5	+2.7	Phillipsburg	99	4	3 stations	13	1	3.33	+0.82	Oswego	10.64	Elkhart	0.14
Kentucky	60.0	+4.0	3 stations	90	[1] 6	Farmers	23	19	3.54	−0.49	Russellville	5.27	Whitesburg	1.63
Louisiana	70.9	+3.9	Donaldsonville	95	25	Robeline	41	12	3.22	−1.48	Winnsboro	7.05	Clinton	1.40
Maryland-Delaware	55.4	+2.9	Millsboro, Del	95	8	Oakland, Md	25	[1] 23	6.47	+3.11	Frostburg, Md	8.43	Public Landing, Md.	4.61
Michigan	44.8	+2.0	Jackson	88	6	Atlanta	1	2	5.34	+2.84	Lake City	11.71	Calumet	0.46
Minnesota	43.7	+1.2	Tracy	89	4	Itasca State Park	9	1	1.96	+0.02	Lynd	8.11	Redby	0.39
Mississippi	67.7	+3.6	Aberdeen	95	4	Pittsboro	37	17	4.53	−0.85	Bonneville	8.58	Fayette	2.15
Missouri	57.4	+2.3	Jefferson City	96	4	3 stations	27	[1] 1	6.15	+2.34	Dean	10.58	Goodland	3.51
Montana	39.4	−3.0	2 stations	80	[1] 20	Outlook	−6	6	0.94	−0.20	Mystic Lake	3.97	Knowlton	0.13
Nebraska	50.0	+1.0	4 stations	96	4	Menzel	−1	1	3.27	+0.83	Auburn	8.30	2 stations	1.16
Nevada	44.1	−4.1	Logandale	92	16	Carson City	3	9	0.74	0.00	Lamoille	2.76	Caliente	0.00
New England	43.2	−0.5	5 stations	90	[1] 7	Van Buren, Me	1	3	5.96	+2.66	Somerset, Vt	11.42	Presque Isle, Me	2.49
New Jersey	51.1	+1.8	Belvidere	94	8	Layton	25	24	6.43	+2.69	Lakewood	8.74	Cape May	4.63
New Mexico	50.8	+0.5	Newman	92	3	4 stations	8	[1] 1	0.20	−0.82	Chama	1.50	51 stations	0.00
New York	45.9	+1.5	Port Jervis	93	17	Dannemora	8	2	6.31	+3.43	West Berne	9.47	Chazy	2.68
North Carolina	61.2	+3.4	2 stations	95	[1] 6	Mount Mitchell	18	17	3.12	−0.57	Murphy	6.21	Wenona	0.74
North Dakota	41.5	−0.2	Hankinson	85	3	Epping	−9	1	1.31	−0.07	Fullerton	3.03	Fairfield	0.04
Ohio	53.2	+3.6	2 stations	90	7	Dover	20	2	4.88	+1.64	Hiram	7.62	Ironton	2.16
Oklahoma	63.6	+3.9	2 stations	95	30	Kenton	18	11	2.90	−0.86	Wyandotte	9.94	Cheyenne	0.03
Oregon	44.4	−3.0	Umatilla	85	26	Meacham	−6	10	3.11	+0.62	Valsetz	12.28	Morgan	0.09
Pennsylvania	51.4	+2.6	Stroudsburg	94	7	Gouldsboro	19	2	6.12	+2.75	Elk Lick	8.94	Center Hall	3.31
South Carolina	63.7	+1.4	2 stations	92	[1] 6	2 stations	33	[1] 17	4.30	+1.20	Chappells	7.47	Charleston	1.88
South Dakota	46.2	+1.0	Alexandria	90	4	Hot Springs	6	1	2.48	+0.39	Arlington	4.89	Camp Crook	0.10
Tennessee	61.9	+3.2	Kingsport	89	[1] 6	Rugby	27	2	5.26	+0.72	Waynesboro	8.83	Johnson City	1.75
Texas	69.7	+3.7	Mercedes	102	24	Dalhart	23	11	2.42	−0.83	Harrisburg	11.13	7 stations	0.00
Utah	44.0	−2.8	St. George	89	16	2 stations	0	[1] 4	1.92	+0.53	Silver Lake	7.03	Lon	T.
Virginia	58.5	+4.0	2 stations	96	7	2 stations	22	[1] 2	4.05	+0.70	Mount Weather	7.44	Wallaceton	0.93
Washington	44.7	−3.2	Wahluke	87	26	3 stations	11	[1] 1	2.89	+0.39	Cougar	12.58	2 stations	0.00
West Virginia	55.4	+3.9	Williamson	94	9	Pickens	18	19	4.54	+1.15	Stony River Dam	8.78	Logan	2.09
Wisconsin	45.5	+2.1	Racine	86	[1] 6	High Falls	10	11	3.94	+1.53	Manitowoc	7.74	Danbury	0.34
Wyoming	37.9	−2.0	Basin	79	16	Lake Yellowstone	−11	7	2.03	+0.53	Middle Fork (near)	5.19	Spencer (near)	0.27
Alaska (March)	11.0	−2.6	Calder	54	28	Tanana	−52	3	2.23	+0.53	Latouche	17.09	McKinley Park	0.02
Hawaii	71.5	+1.3	Kaanapali	92	[1] 20	2 stations	47	[1] 1	6.95	−2.33	Puohakamoa (No. 2)	30.00	5 stations	0.00
Porto Rico	74.9	−0.3	Dorado	94	16	Jayuya	53	10	2.22	−2.53	Maricao	9.90	Josefa	0.00

[1] For description of tables and charts, see REVIEW, January, 1929, p. 36

[1] Other dates also.

TABLE 1.—*Climatological data for Weather Bureau stations, April, 1929*

District and station	Elevation of instruments: Barometer above sea level	Elevation of instruments: Thermometer above ground	Elevation of instruments: Anemometer above ground	Pressure: Station, reduced to mean of 24 hours	Pressure: Sea level, reduced to mean of 24 hours	Pressure: Departure from normal	Temperature of the air: Mean max. + mean min. ÷2	Temperature of the air: Departure from normal	Temperature of the air: Maximum	Temperature of the air: Date	Temperature of the air: Mean maximum	Temperature of the air: Minimum	Temperature of the air: Date	Temperature of the air: Mean minimum	Temperature of the air: Greatest daily range	Mean wet thermometer	Mean temperature of the dew-point	Mean relative humidity	Precipitation: Total	Precipitation: Departure from normal	Precipitation: Days with 0.01, or more	Wind: Total movement	Wind: Prevailing direction	Wind: Maximum velocity: Miles per hour	Wind: Maximum velocity: Direction	Wind: Maximum velocity: Date	Clear days	Partly cloudy days	Cloudy days	Average cloudiness, tenths	Total snowfall	Snow, sleet, and ice on ground at end of month
New England	*Ft.*	*Ft.*	*Ft.*	*In.*	*In.*	*In.*	*° F.* 44.3	*° F.* +0.4	*°F.*		*°F.*	*°F.*		*°F.*	*° F.*	*°F.*	*°F.*	% 75	*In.* 5.36	*In.* +2.3		*Miles*								*0–10* 6.8	*In.*	*In.*
Eastport	76	67	85	29.81	29.90	−0.03	38.2	−0.8	58	7	44	23	13	32	27	34	29	72	2.69	−0.2	13	8,712	s.	54	e.	16	5	6	19	7.4	4.6	0.0
Greenville, Me	1,070	6		28.71	29.88		36.2		65	7	46	10	15	27	38				5.71		14	5,753	se.	33		2	8	5	17		18.2	
Portland, Me	103	82	117	29.81	29.93	−.03	42.5	−0.5	80	7	50	24	14	35	43	37	31	70	4.61	+1.2	13	6,712	ne.	37	ne.	16	9	7	14	6.1	4.7	0.0
Concord	289	70	79	29.58	29.90	−.09	43.0	−0.4	80	7	52	22	11	34	45				3.40	+0.6	13	4,549	ne.	28	w.	29	8	8	14	6.3	2.9	0.0
Burlington	403	11	48	29.45	29.90	−.09	42.6	−0.7	71	8	50	16	2	35	32				3.74	+1.6	16	6,816	s.	46	s.	28	1	8	21	8.1	7.7	0.0
Northfield	876	12	60	28.97	29.95	−.07	40.2	−0.1	78	8	50	15	2	31	38	36	31	73	4.22	+1.9	16	4,931	s.	30	sw.	2	1	9	20	8.0	23.0	0.0
Boston	125	115	188	29.76	29.90	−.07	47.1	+0.7	84	8	54	29	2	40	43	42	38	73	7.52	+4.2	16	7,199	w.	33	w.	2	6	7	17	7.0	0.6	0.0
Nantucket	12	14	90	29.87	29.88	−.09	45.2	+1.8	68	8	51	34	14	39	20	42	38	82	6.28	+3.3	17	12,737	sw.	61	ne.	16	8	10	12	6.1	T.	0.0
Block Island	26	11	46	29.84	29.87	−.11	45.4	+1.4	69	8	51	34	2	40	29	42	39	84	5.66	+2.1	17	13,248	w.	54	ne.	16	7	9	14	6.2	0.2	0.0
Providence	160	215	251	29.72	29.90	−.08	47.2	+0.6	84	7	55	29	11	39	44	42	35	68	5.94	+2.7	15	8,978	nw.	59	nw.	2	8	5	17	6.4	0.7	0.0
Hartford	159	122		29.73	29.91	−.08	48.0	+1.3	90	7	56	28	2	40	47				7.66	+4.3	18		sw.				9	4	17	6.5	1.9	0.0
New Haven	106	74	153	29.79	29.91	−.08	48.1	+0.9	82	7	56	32	2	41	37	43	39	76	7.25	+3.7	17	7,450	n.	47	ne.	16	10	4	16	6.4	T.	0.0
Middle Atlantic States							54.4	+3.1										70	5.03	+2.0										6.1		
Albany	97	107	115	29.80	29.90	−.10	47.5	+0.7	88	8	55	23	2	40	33	42	38	75	6.31	+3.8	21	5,211	sw.	30	s.	1	7	7	16	6.8	4.6	0.0
Binghamton	871	10	84	28.97	29.90	−.12	48.3	+2.9	85	7	57	25	2	39	39				7.27	+4.8	20	4,752	nw.	34	w.	1	4	8	18	7.2	3.0	0.0
New York	314	414	454	29.56	29.90	−.10	50.6	+1.2	86	7	58	32	2	43	40	44	38	68	5.76	+2.5	15	11,825	nw.	62	nw.	1	5	8	17	7.2	T.	0.0
Bellefonte	1,050	5	36	28.80	29.91		49.4		84	7	60	28	2	38	42	44	40	73	5.34		16		w.				7	7	16	6.9	1.5	0.0
Harrisburg	374	94	104	29.52	29.92	−.10	53.4	+2.5	89	8	62	33	16	44	35	46	40	65	6.03	+3.3	15	5,474	ne.	38	s.	1	6	12	12	6.5	T.	0.0
Philadelphia	114	123	367	29.79	29.92	−.09	55.2	+3.1	90	7	64	37	17	46	35	49	44	73	6.44	+3.4	16	10,736	sw.	50	ne.	16	7	6	17	6.6	0.0	0.0
Reading	325	81	98	29.56	29.91		53.4		88	7	62	34	2	44	35	46	39	65	5.32	+2.0	13	5,202	nw.	35	ne.	16	8	8	14	6.6	0.0	0.0
Scranton	805	111	119	29.05	29.92	−.09	50.0	+1.9	86	7	59	27	2	41	33	44	40	73	4.68	+1.9	18	5,598	sw.	34	w.	2	6	5	19	7.3	1.5	0.0
Atlantic City	52	37	172	29.85	29.91	−.09	52.4	+4.6	86	6	59	38	17	45	35	47	42	74	5.63	+2.6	15	14,416	w.	78	ne.	16	10	7	13	5.5	0.0	0.0
Cape May	17	13	49				53.0	+4.6	84	6	61	36	22	45	35	49	46	81	4.63		15		s.				9	8	13		0.0	0.0
Sandy Hook	22	10	55	29.88	29.90		49.4		85	8	56	36	2	43	37	44	41	78	5.08	+1.5	18	11,732	ne.	60	ne.	16	6	6	18	6.7	0.0	0.0
Trenton	190	159	183	29.70	29.90		52.2		88	7	62	34	2	43	41	46	40	71	5.34	+2.4	16	8,874	ne.	50	ne.	16	6	6	18	6.8	0.0	0.0
Baltimore	123	100	215	29.78	29.91	−.10	57.4	+3.8	93	7	67	36	16	48	35	50	44	66	6.73	+3.4	17	7,952	sw.	42	sw.	1	11	8	11	5.8	T.	0.0
Washington	112	62	85	29.79	29.91	−.11	57.6	+4.3	94	7	69	38	2	47	36	49	43	64	6.10	+2.8	13	5,307	s.	30	nw.	1	9	10	11	5.8	0.0	0.0
Cape Henry	18	8	54	29.90	29.92		61.0		93	8	70	39	23	52	36	54	49	70	1.45	−1.8	7	9,468	sw.	40	nw.	17	13	8	9	5.0	0.0	0.0
Lynchburg	681	153	188	29.19	29.93	−.09	59.6	+2.3	90	6	71	36	16	48	40	51	44	62	5.76	+2.8	10	6,188	w.	39	nw.	1	14	9	7	4.7	0.0	0.0
Norfolk	91	170	205	29.85	29.95	−.06	61.6	+4.8	92	6	71	40	18	52	31	53	48	67	1.06	−2.2	7	10,560	sw.	44	sw.	1	11	10	9	5.0	0.0	0.0
Richmond	144	11	52	29.79	29.94	−.08	60.2	+3.6	94	7	71	38	18	49	35	52	45	65	3.50	0.0	9	6,391	sw.	39	sw.	1	15	6	9	4.5	0.0	0.0
Wytheville	2,304	49	55	27.58	29.94	−.09	55.2	+3.2	80	6	66	31	23	44	37	47	41	63	3.11	+0.1	11	5,458	w.	33	sw.	1	11	12	7	4.9	T.	0.0
South Atlantic States							65.1	+3.3										70	3.12	+0.1										5.0		
Asheville	2,253	70	84	27.64	29.97	−.06	57.0	+3.1	84	7	68	35	19	46	36	49	42	64	2.76	−0.3	9	5,655	se.	28	nw.	17	14	10	6	4.3	0.0	0.0
Charlotte	779	55	62	29.14	29.98	−.05	63.6	+3.8	90	6	74	42	17	53	30	54	47	62	3.35	0.0	9	3,726	sw.	21	sw.	1	12	10	8	4.9	0.0	0.0
Greensboro	886	5	56	29.02	29.98		59.8		90	7	73	32	19	47	41	52	47	69	5.18		11	6,591	sw.	31	ne.	15	9	12	9	5.3	0.0	0.0
Hatteras	11	11	80	29.95	29.96	−.05	63.0	+3.2	78	29	70	47	20	56	24	59	55	77	1.56	−2.0	9	9,859	sw.	37	sw.	25	15	6	9	4.0	0.0	0.0
Raleigh	376	103	110	29.56	29.96	−.07	62.6	+3.2	91	7	73	40	18	52	33	54	48	64	2.92	−0.6	8	5,952	sw.	27	sw.	1	10	11	9	5.1	0.0	0.0
Wilmington	78	81	91	29.92	30.00	−.03	65.4	+3.4	88	6	74	42	18	56	36	59	55	76	1.64	−1.0	8	5,445	sw.	29	nw.	22	14	8	8	4.8	0.0	0.0
Charleston	48	11	92	29.96	30.01	−.02	68.1	+3.6	85	22	76	46	17	61	30	62	58	75	1.88	−0.6	10	6,936	sw.	28	nw.	28	10	10	10	5.2	0.0	0.0
Columbia, S. C	351	41	57	29.62	30.00	−.03	65.7	+2.4	89	6	76	42	18	55	29	58	53	71	4.20	+1.3	10	4,814	s.	26	w.	22	12	12	6	5.0	0.0	0.0
Due West	711	10	55	29.25	30.02		63.0		86	6	74	40	17	52	31				5.44		11	6,090	sw.	34	nw.	22	12	11	7	5.0	0.0	0.0
Greenville, S. C	1,039	139	146	28.88	29.98		63.2	+4.6	86	6	73	41	18	54	29	54	47	63	5.73	+2.0	8	6,247	sw.	31	w.	21	11	8	11	5.3	0.0	0.0
Augusta	182	62	77	29.79	29.98	−.05	67.3	+3.1	90	6	78	44	17	56	30	58	53	66	3.19	0.0	9	3,458	nw.	32	s.	25	8	10	6	5.0	0.0	0.0
Savannah	65	150	194	29.95	30.02	−.01	69.2	+3.2	88	8	78	45	17	60	27	61	58	75	1.95	−0.6	9	8,105	s.	36	nw.	15	9	8	13	5.7	0.0	0.0
Jacksonville	43	209	245	29.97	30.02	−.02	71.4	+2.7	86	25	79	50	17	64	23	63	60	74	5.09	+2.7	6	8,018	sw.	43	nw.	15	8	14	8	5.4	0.0	0.0
Florida Peninsula							76.3	+3.2										72	2.07	0.0										3.6		
Key West	22	10	64	29.99	30.01	−.01	78.5	+2.8	87	21	84	68	18	74	13	70	67	72	0.40	−0.9	5	7,189	se.	30	w.	16	21	9	0	2.4	0.0	0.0
Miami	25	71	164	30.01	30.04	.00	75.7	+2.9	86	15	81	56	18	70	22	68	65	71	3.24	+0.2	7	7,378	e.	36	s.	15	12	15	3	4.3	0.0	0.0
Tampa	35	79	87	29.98	30.02	−.04	74.7	+3.8	87	24	84	58	18	66	24	66	63	73	2.58	+0.6	6	4,260	sw.	26	w.	15	11	13	6	4.6	0.0	0.0
Titusville	44	5		29.98	30.03		74.6		93	22	84	51	18	65	26				1.81		6		sw.				17	12	1	2.9	0.0	0.0
East Gulf States							68.2	+3.5										74	4.83	+0.6										5.4		
Atlanta	1,173	190	216	28.76	30.00	−.03	64.6	+3.6	85	6	73	42	17	56	28	56	51	67	6.16	+2.6	11	7,272	nw.	34	nw.	16	8	11	11	6.0	0.0	0.0
Macon	370	78	87	29.60	30.00	−.03	67.0	+2.9	88	6	78	45	13	56	30	59	54	69	2.22	−0.9	9	4,272	s.	27	nw.	11	9	12	9	5.0	0.0	0.0
Thomasville	273	49	58	29.72	30.01	−.02	70.5	+3.8	86	7	80	47	17	61	26	62	57	71	4.40	+1.1	8	3,212	sw.	26	sw.	25	9	8	13	5.9	0.0	0.0
Apalachicola	36	42	49	29.97	30.02		70.6		82	22	76	55	17	65	18	66	64	81	8.23	+5.4	7	5,245	s.	26	nw.	11	13	7	10	4.8	0.0	0.0
Pensacola	56	149	185	29.94	30.00	−.02	70.2	+3.5	83	22	75	54	17	66	17	65	62	78	3.30	−0.7	7	9,102	s.	36	w.	15	10	10	10	5.3	0.0	0.0
Anniston	741	9	57	29.22	30.01	−.02	64.2	+3.8	87	7	76	39	17	52	33				6.13	+1.8	14	3,508	nw.	20	w.	25	9	14	7	5.2	0.0	0.0
Birmingham	700	11	48	29.24	30.00	−.02	65.8	+2.5	85	8	76	41	17	56	31	57	52	69	6.85	+2.0	12	5,009	s.	27	se.	24	8	12	10	5.9	0.0	0.0
Mobile	57	125	161	29.93	29.99	−.03	71.1	+4.8	86	25	79	52	17	64	24	64	61	76	3.58	−1.0	8	6,960	s.	26	nw.	15	9	11	10	5.2	0.0	0.0
Montgomery	223	100	112	29.76	30.01	−.02	68.2	+2.9	86	25	78	48	17	58	26	62	59	77	7.56	+3.3	12	4,525	s.	27	nw.	25	10	14	6	5.0	0.0	0.0
Corinth	469	6					65.2		87	8	75	41	17	56	33				6.20		12		se.				4	18	8		0.0	0.0
Meridian	375	87	95	29.58	29.98	−.04	67.6	+3.6	85	5	77	45	17	58	28	60	55	71	2.73	−2.0	10	4,378	s.	29	w.	24	9	11	10	5.6	0.0	0.0
Vicksburg	247	65	73	29.70	29.98	−.02	68.1	+2.5	84	29	76	51	16	60	24	61	58	75	4.82	−0.4	10	4,996	se.	28	nw.	24	10	8	12	5.6	0.0	0.0
New Orleans	53	76	84	29.92	29.98	−.02	73.3	+4.5	90	25	81	58	16	66	19	66	63	76	1.98	−3.3	4	4,731	se.	25	nw.	20	9	12	9	5.2	0.0	0.0
West Gulf States							70.2	+3.7										73	3.71	0.0										5.1		
Shreveport	249	77	93	29.67	29.94	−.03	69.2	+3.4	90	29	79	49	1	60	27	61	56	68	3.09	−1.5	8	4,565	se.	40	w.	14	10	13	7	4.8	0.0	0.0
Bentonville	1,303	11	44	28.52	29.88	−.08	60.4	+3.5	82	4	70	33	1	51	32				7.85		15	4,742	s.	30	s.	5	17	9	4		0.0	0.0
Fort Smith	457	79	94	29.41	29.89	−.07	64.4	+2.6	85	20	74	39	1	55	36	57	51	68	3.78	−0.2	7	6,142	e.	30	se.	30	7	13	10	6.0	0.0	0.0
Little Rock	357	136	153	29.54	29.92	−.06	64.7	+2.6	84	4	73	44	1	56	29	57	51	67	4.93	−0.3	12	6,380	s.	27	nw.	25	7	7	16	6.7	0.0	0.0
Austin	605	136	148	29.26	29.89		71.6	+3.8	93	28	81	52	16	62	26	63	59	71	2.72	−1.6	8	6,028	se.	30	w.	8	5	15	10	6.0	0.0	0.0
Brownsville	57	83	100	29.80	29.86		78.7	+5.0	96	14	85	62	15	72	26	71	69	82	0.88	−0.6	2	8,516	se.	33	se.	5	9	17	4	5.1	0.0	0.0
Corpus Christi	20	11	78	29.86	29.88	−.07	76.6	+5.8	88	13	81	59	15	72	27	71	69	83	0.86	−0.9	4	9,096	se.	31	e.	21	2	9	19	7.5	0.0	0.0
Dallas	512	220	227	29.36	29.90		68.4		88	30	78	44	1	59	28				2.64	−1.6	7	9,885	se.	55	se.	19	11	13	6	4.3	0.0	0.0
Fort Worth	670	106	114	29.17	29.88	−.06	68.4	+3.4	89	30	78	45	1	59	29	59	53	66	2.06	−2.0	7	7,636	s.	32	s.	6	9	8	13	5.4	0.0	0.0
Galveston	54	106	114	29.88	29.94	−.03	73.4	+4.7	83	21	78	59	16	69	16	69	66	83	9.92	+6.9	7	8,930	s.	42	se.	13	6	18	6	5.2	0.0	0.0
Groesbeck	461	11	56	29.43	29.91		69.4		88	20	78	48	1	60	29				3.45	−1.2	9	8,341	s.	32	e.	13	9	12	9	5.3	0.0	0.0
Houston	138	292	314	29.79	29.94		72.4	+3.1	89	28	80	56	16	65	23				8.02	+4.4	10	9,196	se.	44	w.	8	6	16	8	5.7	0.0	0.0
Palestine	510	64	72	29.40	29.93	−.03	69.1	+3.1	88	29	78	48	16	60	29	61	57	70	3.75	−0.7	5	5,973	s.	27	nw.	14	8	13	9	5.7	0.0	0.0
Port Arthur	34	58	66	29.90	29.94		73.2		87	21	79	53	16	67	21				2.45		7	6,174	s.	31	nw.	11	9	12	9	5.4	0.0	0.0
San Antonio	603	119	132	29.17	29.89	−.04	72.8	+3.7	94	24	82	56	12	64	29	64	60	71	2.37	−0.8	8	5,336	se.	30	nw.	14	5	12	13	6.5	0.0	0.0
Taylor	583	55	63	29.34	29.95	.00	70.8	+3.3	91	28	80	49	26	61	26				3.47	−0.3	5	6,636	se.	30	sw.	20	5	10	9	5.8	0.0	0.0

TABLE 1.—*Climatological data for Weather Bureau stations, April, 1929*—Continued

District and station	Elevation of instruments: Barometer above sea level	Elevation of instruments: Thermometer above ground	Elevation of instruments: Anemometer above ground	Pressure: Station reduced to mean of 24 hours	Pressure: Sea level, reduced to mean of 24 hours	Pressure: Departure from normal	Temperature of the air: Mean max. +2 mean min. +2	Temperature of the air: Departure from normal	Temperature of the air: Maximum	Temperature of the air: Date	Temperature of the air: Mean maximum	Temperature of the air: Minimum	Temperature of the air: Date	Temperature of the air: Mean minimum	Temperature of the air: Greatest daily range	Mean wet thermometer	Mean temperature of the dew-point	Mean relative humidity	Precipitation: Total	Precipitation: Departure from normal	Precipitation: Days with 0.01, or more	Wind: Total movement	Wind: Prevailing direction	Wind: Maximum velocity: Miles per hour	Wind: Maximum velocity: Direction	Wind: Maximum velocity: Date	Clear days	Partly cloudy days	Cloudy days	Average cloudiness, tenths	Total snowfall	Snow, sleet, and ice on ground at end of month
Ohio Valley and Tennessee	*Ft.*	*Ft.*	*Ft.*	*In.*	*In.*	*In.*	*° F.*	*° F.*	*° F*		*° F*	*° F.*	*° F*	*° F*	%	*In.*	*In.*		*Miles*										*0–10*	*In.*	*In.*
							58.1	+3.3										66	4.45	+0.8									6.0		
Chattanooga	762	190	215	29.17	29.98	−0.05	63.2	+2.9	85	7	72	44	2	54	26	54	48	63	6.70	+1.8	14	5,933	sw.	43	se.	25	6	13	11	6.0	0.0	0.0
Knoxville	995	102	111	28.92	29.98	−.05	61.6	+3.6	84	7	72	40	18	51	30	53	47	65	3.46	−0.7	12	4,963	sw.	35	sw.	25	5	16	9	5.7	0.0	0.0
Memphis	399	76	97	29.51	29.93	−.07	64.2	+2.4	83	6	72	47	16	57	23	57	52	69	8.50	+3.7	13	5,456	s.	36	w.	25	7	6	17	6.3	0.0	0.0
Nashville	546	168	191	29.40	29.98	−.03	62.4	+3.4	84	21	72	42	17	53	30	54	47	64	3.93	−0.2	13	7,039	s.	48	s.	24	7	13	10	5.8	0.0	0.0
Lexington	989	193	230	28.90	29.96	−.06	57.8	+3.5	83	7	68	35	2	48	31				2.99	−0.5	16	10,580	sw.	52	w.	1	16	9	5	4.1	0.0	0.0
Louisville	525	188	234	29.38	29.96	−.05	60.0	+3.6	85	7	70	36	2	50	32	51	45	65	4.31	+0.4	14	8,858	s.	48	sw.	1	8	15	7	5.2	0.0	0.0
Evansville	431	76	116	29.49	29.96	−.04	59.5	+2.8	81	4	68	40	2	51	27	52	48	70	3.84	−0.1	14	7,832	s.	38	sw.	25	9	11	10	5.5	0.0	0.0
Indianapolis	822	194	230	29.04	29.92	−.08	55.6	+2.9	82	6	65	32	1	46	36	48	41	65	4.28	+0.7	15	9,334	s.	44	w.	1	6	14	10	6.3	T.	0.0
Royal Center	736	11	55	29.11	29.91	.....	51.7	.....	82	6	62	29	2	41	32	.....	.....	.....	3.95	+0.9	13	8,637	sw.	44	sw.	1	6	9	15	6.6	T.	0.0
Terre Haute	575	96	129	29.30	29.92	.....	56.2	.....	84	4	66	33	1	47	32	49	44	69	5.99	+2.3	14	8,143	s.	34	w.	1	5	13	12	6.2	T.	0.0
Cincinnati	627	11	51	29.26	29.94	−.07	56.6	+4.2	85	5	67	33	2	47	34	49	43	66	3.98	+0.9	13	6,465	sw.	36	sw.	1	9	8	13	5.9	0.0	0.0
Columbus	822	179	222	29.06	29.94	−.08	54.4	+3.2	83	6	64	30	2	45	33	48	42	69	3.71	+0.8	13	7,922	s.	40	nw.	28	6	10	14	6.5	T.	0.0
Dayton	899	137	173	28.97	29.93	.....	55.4	+3.8	83	6	65	32	2	46	35	48	42	67	4.01	+0.8	13	7,805	sw.	46	nw.	28	3	15	12	6.6	T.	0.0
Elkins	1,947	59	67	27.90	29.95	−.08	52.6	+3.8	82	8	64	26	19	41	44	46	40	67	4.49	+0.9	14	5,104	w.	37	sw.	1	4	13	13	6.6	0.8	0.0
Parkersburg	637	77	82	29.30	29.95	−.08	57.2	+3.8	87	6	68	31	19	47	37	48	41	62	2.84	−0.4	15	4,944	sw.	34	nw.	28	11	4	15	6.3	0.0	0.0
Pittsburgh	842	353	410	29.02	29.92	−.10	53.4	+2.2	83	7	62	31	2	44	36	46	40	66	4.29	+1.4	16	8,565	sw.	53	w.	1	4	12	14	7.3	T.	0.0
Lower Lake Region							48.3	+2.9										74	5.59	+3.0									6.8		
Buffalo	767	247	280	29.06	29.90	−.11	43.8	+1.0	70	7	52	22	2	36	37	40	36	78	5.02	+2.5	18	11,967	sw.	78	sw.	1	4	9	17	7.2	0.7	0.0
Canton	448	10	61	29.39	29.87	.....	43.5	+1.0	74	8	52	14	2	35	41	.....	.....	.....	3.68	+1.5	17	7,934	e.	45	sw.	1	6	7	17	7.0	3.8	0.0
Ithaca	836	5	100	28.97	29.89	.....	46.9	.....	84	6	56	23	2	38	40	42	38	76	6.34	+3.8	19	7,103	nw.	43	sw.	1	4	7	19	7.3	9.2	0.0
Oswego	335	76	91	29.52	29.89	−.12	44.8	+1.2	76	6	52	22	2	37	39	42	38	78	4.11	+1.8	20	7,290	w.	40	w.	1	4	9	17	7.3	T.	0.0
Rochester	523	86	102	29.34	29.91	−.10	46.8	+1.9	77	6	56	23	2	38	42	42	37	71	5.41	+3.1	22	6,583	w.	45	sw.	1	7	5	18	7.2	0.3	0.0
Syracuse	596	65	79	29.26	29.91	−.10	48.3	+3.9	81	6	56	22	2	40	38	.....	.....	.....	7.61	+5.1	22	5,460	e.	30	sw.	1	2	12	16	7.1	3.2	0.0
Erie	714	130	166	29.14	29.91	−.11	48.6	+3.5	81	7	56	28	2	42	36	44	39	73	5.57	+2.8	18	9,960	sw.	62	sw.	1	5	9	16	6.7	T.	0.0
Cleveland	762	190	201	29.09	29.92	−.10	50.6	+4.4	84	6	58	30	2	43	35	45	40	70	5.26	+2.8	14	9,459	sw.	60	sw.	1	8	11	16	7.1	T.	0.0
Sandusky	629	5	67	29.23	29.91	−.11	52.0	+4.8	85	6	60	28	2	44	35	.....	.....	.....	5.76	+3.2	13	7,430	sw.	40	sw.	1	3	13	14	6.9	T.	0.0
Toledo	628	208	243	29.24	29.92	−.09	50.8	+3.2	83	6	59	29	2	42	33	45	40	72	7.13	+4.5	14	10,710	sw.	58	sw.	1	11	6	13	5.7	T.	0.0
Fort Wayne	856	113	124	28.98	29.91	.....	52.2	+2.9	83	6	62	30	2	43	35	45	40	69	4.49	+1.4	14	7,518	sw.	40	s.	25	5	12	13	6.5	T.	0.0
Detroit	730	218	258	29.12	29.91	−.11	49.8	+3.6	83	6	58	28	2	42	31	45	42	80	5.65	+3.2	15	8,081	sw.	53	sw.	1	9	8	13	6.3	T.	0.0
Upper Lake Region							44.0	+2.5										74	4.12	+1.7									5.7		
Alpena	609	13	92	29.25	29.92	−.10	40.7	+2.1	82	6	49	12	2	32	46	37	32	72	3.67	+1.4	15	8,118	nw.	36	nw.	1	11	10	9	5.3	8.7	0.0
Escanaba	612	54	60	29.26	29.94	−.08	39.9	+2.0	77	6	47	22	1	33	38	35	30	74	3.51	+1.3	13	7,156	s.	37	n.	1	14	6	10	4.5	10.6	0.0
Grand Haven	632	54	89	29.21	29.90	−.11	45.7	+2.0	72	6	54	27	1	38	29	41	37	76	4.11	+1.4	14	8,798	s.	38	nw.	1	7	9	14	6.1	0.1	0.0
Grand Rapids	707	70	87	29.13	29.91	−.11	48.6	+1.6	80	6	58	27	1	40	34	43	37	69	5.61	+2.8	12	4,670	w.	22	w.	1	6	10	14	6.8	T.	0.0
Houghton	668	64	99	29.18	29.92	−.10	39.8	+2.1	73	3	48	24	1	32	37	.....	.....	.....	0.81	−1.5	4	7,261	e.	38	w.	7	10	9	11	5.6	2.1	0.7
Lansing	878	6	49	28.96	29.91	.....	47.8	+2.2	82	6	58	24	2	38	39	43	39	78	5.54	+3.0	14	4,854	sw.	27	nw.	1	9	10	11	5.8	0.6	0.0
Ludington	637	60	66	29.20	29.90	.....	43.1	.....	67	6	50	24	1	36	27	40	38	85	6.47	+3.9	14	7,205	n.	28	s.	5	12	4	14	5.2	2.2	0.0
Marquette	734	77	111	29.12	29.94	−.08	40.0	+2.2	72	6	47	22	1	33	35	35	30	72	2.40	0.0	11	6,034	n.	34	w.	6	10	6	14	5.7	11.5	2.0
Port Huron	638	70	120	29.20	29.91	−.11	46.8	+3.8	83	6	55	24	2	39	30	42	37	74	5.92	+3.7	13	8,586	sw.	41	w.	1	5	18	7	5.8	0.1	0.0
Sault Sainte Marie	614	11	52	29.23	29.94	−.09	40.0	+2.6	71	6	48	11	2	32	35	34	29	71	1.53	−0.7	12	6,225	nw.	30	nw.	26	6	15	9	5.0	4.6	T.
Chicago	673	7	131	29.18	29.91	−.09	51.1	+4.2	84	6	58	31	1	44	31	45	40	72	4.79	+2.0	14	8,367	ne.	37	sw.	1	9	6	15	6.4	T.	0.0
Green Bay	617	109	141	29.22	29.89	−.12	45.0	+1.8	77	6	53	24	1	37	34	40	36	76	6.47	+3.8	12	7,815	s.	48	ne.	1	8	8	14	6.0	12.2	0.0
Milwaukee	681	125	221	29.15	29.90	−.09	47.5	+3.7	83	6	55	26	1	40	34	42	37	72	5.26	+2.6	15	9,767	n.	37	n.	25	9	9	12	6.1	T.	0.0
Duluth	1,133	5	47	28.68	29.92	−.09	38.8	+1.8	74	3	48	19	1	30	40	33	28	71	1.61	−0.4	7	8,904	ne.	37	ne.	11	13	8	9	5.2	3.9	0.0
North Dakota							41.6	+.08										68	1.95	+0.2									5.6		
Moorhead	940	50	58	28.86	29.89	−.10	43.1	+2.5	80	4	54	22	9	32	38	37	31	68	1.99	−0.2	7	5,695	s.	23	w.	1	9	8	13	6.1	5.7	0.0
Bismarck	1,674	8	57	28.09	29.89	−.08	43.2	+1.1	74	3	54	20	8	32	44	37	30	65	1.87	+0.4	11	5,952	n.	26	ne.	24	10	10	10	5.5	1.8	0.0
Devils Lake	1,478	11	44	28.30	29.90	−.09	39.8	+1.0	71	3	51	16	8	29	40	34	28	71	1.54	0.0	11	6,634	ne.	35	ne.	5	9	12	9	5.3	1.9	0.0
Ellendale	1,457	10	56	28.32	29.90	.....	42.6	.....	80	4	54	19	12	32	45	.....	.....	.....	2.51	+0.4	10	8,747	ne.	35	nw.	6	8	9	13	6.1	8.3	0.0
Grand Forks	833	12	67	.....	.....	.....	42.0	.....	71	26	53	19	9	31	43	36	.....	.....	1.70	.....	7	.....	nw.	.....	w.	6	14	9	7	.....	2.3	0.0
Williston	1,878	41	48	27.90	29.90	−.06	40.4	−1.6	68	26	52	12	8	29	35	34	28	67	1.84	+0.6	6	5,410	w.	32	w.	15	12	11	7	4.9	12.5	0.0
Upper Mississippi Valley							52.5	+2.3										70	4.02	+1.1									6.2		
Minneapolis	918	102	208	28.87	29.86	.....	46.8	+0.4	78	5	56	21	1	38	30	.....	.....	.....	1.62	−0.6	13	7,729	s.	36	n.	25	5	9	16	6.8	9.2	0.0
St. Paul	837	236	261	28.96	29.88	−.11	46.4	+0.8	75	5	56	21	1	37	29	.....	.....	.....	2.43	+0.1	13	8,049	se.	41	sw.	5	6	6	18	6.9	8.7	0.0
La Crosse	714	11	48	29.10	29.88	−.10	49.6	+2.4	80	4	59	23	1	40	35	43	38	68	3.56	+1.1	13	3,600	s.	23	sw.	5	6	11	13	6.7	4.5	0.0
Madison	974	70	78	28.84	29.90	−.11	48.0	+2.6	79	6	56	22	1	40	33	43	38	71	4.33	+1.6	14	6,748	ne.	30	ne.	25	10	6	14	6.2	2.9	0.0
Wausau	1,247	4	64	28.55	29.90	.....	45.6	.....	75	4	56	21	1	36	36	.....	.....	.....	3.64	+1.0	10	4,503	e.	21	e.	10	9	9	12	5.8	10.9	0.0
Charles City	1,015	10	51	28.81	29.89	−.09	48.8	+2.4	82	4	58	19	2	39	36	44	30	72	4.89	+2.4	11	4,845	se.	27	sw.	5	11	11	8	5.5	3.8	0.0
Davenport	606	71	79	29.22	29.88	−.10	53.0	+3.1	83	4	62	26	1	44	27	47	42	72	5.49	+2.8	14	8,943	ne.	41	w.	27	7	9	14	6.5	T.	0.0
Des Moines	861	84	97	28.95	29.86	−.11	53.0	+2.9	89	4	62	26	1	44	37	47	41	69	4.38	+1.5	11	5,872	sw.	32	sw.	5	6	11	13	6.6	0.4	0.0
Dubuque	700	81	96	29.13	29.88	−.10	51.0	+2.4	83	4	60	24	1	42	33	45	39	66	3.47	+0.6	13	4,718	s.	24	n.	25	7	8	15	5.3	0.2	0.0
Keokuk	614	64	78	29.22	29.90	−.08	54.4	+2.1	85	4	63	29	1	46	31	48	42	66	4.60	+1.6	15	6,110	s.	31	nw.	1	6	9	15	6.8	0.0	0.0
Cairo	358	87	93	29.55	29.93	−.06	61.5	+3.4	80	4	69	43	16	54	24	55	50	71	2.97	−0.8	14	6,987	s.	36	sw.	25	9	5	16	6.2	0.0	0.0
Peoria	609	11	45	29.25	29.91	−.08	53.6	+2.7	86	4	63	29	1	44	29	47	43	72	4.56	+1.2	14	5,834	s.	28	nw.	1	13	6	11	5.3	T.	0.0
Springfield, Ill	636	154	191	29.22	29.89	−.09	54.6	+1.9	86	4	63	31	1	46	31	48	44	70	3.56	0.0	12	10,203	s.	48	sw.	1	6	11	13	6.4	0.0	0.0
Hannibal	534	74	109	29.31	29.88	−.10	56.3	+2.9	88	4	65	32	1	47	34	.....	.....	.....	3.85	+0.7	17	7,702	sw.	31	w.	1	10	8	12	5.8	0.0	0.0
St. Louis	568	265	303	29.29	29.90	−.08	58.2	+2.4	87	4	67	36	1	50	30	51	46	69	6.99	+3.2	15	10,012	sw.	44	w.	1	10	10	10	5.5	0.0	0.0
Missouri Valley							53.3	+2.2										67	4.23	+1.4									5.8		
Columbia, Mo	784	6	84	29.04	29.88	−.10	57.5	+2.6	88	4	67	33	1	48	32	.....	.....	.....	5.74	+2.0	14	6,530	s.	35	s.	24	9	8	13	6.2	0.0	0.0
Kansas City	963	161	181	28.83	29.86	−.10	57.0	+2.2	86	4	65	32	1	49	31	50	45	69	4.78	+1.6	12	8,033	s.	36	nw.	25	10	8	12	6.0	T.	0.0
St. Joseph	967	11	49	28.81	29.85	.....	56.4	.....	88	4	66	31	1	47	38	49	44	68	6.93	+3.9	14	6,954	ne.	36	sw.	30	12	6	12	5.8	0.0	0.0
Springfield, Mo	1,324	98	104	28.50	29.89	−.08	58.9	+2.9	84	4	68	31	1	50	32	52	46	70	3.94	+0.1	16	8,248	s.	34	se.	24	12	12	6	4.5	0.0	0.0
Iola	984	11	50	28.81	29.85	−.10	58.0	+1.8	85	4	68	30	1	48	39	.....	.....	.....	6.19	+2.7	15	5,293	s.	23	s.	5	8	8	14	6.1	0.0	0.0
Topeka	987	92	107	.....	.....	.....	57.2	+2.5	88	4	67	30	1	48	40	.....	.....	.....	5.26	+2.5	10	7,762	sw.	35	n.	25	13	6	11	5.2	0.0	0.0
Lincoln	1,189	11	81	28.58	29.84	−.10	54.2	+2.7	94	4	64	26	1	44	43	46	39	65	2.93	+0.4	15	7,422	s.	36	s.	5	6	12	12	6.4	0.0	0.0
Omaha	1,105	115	122	28.68	29.86	−.09	54.2	+3.0	94	4	64	27	1	45	41	46	39	63	3.98	+1.5	14	5,698	ne.	34	n.	25	10	9	11	5.8	0.2	0.0
Valentine	2,598	47	54	27.15	29.87	−.07	46.6	+0.9	82	29	58	11	1	35	45	39	32	65	2.44	+0.6	9	6,792	w.	38	w.	5	10	13	7	5.5	4.8	0.0
Sioux City	1,135	94	104	28.65	29.87	−.08	51.5	+3.7	90	4	62	20	1	41	37	44	37	66	2.99	+0.3	9	8,413	s.	49	sw.	5	6	12	12	6.1	1.5	0.0
Huron	1,306	59	74	28.48	29.89	−.07	46.4	+1.3	83	4	58	17	12	35	45	40	33	69	3.41	+1.2	6	6,591	s.	40	w.	5	8	13	9	5.6	11.0	0.0
Pierre	1,572	70	75	.....	29.87	−.08	47.7	+0.9	83	3	60	24	1	36	47	.....	.....	70	3.17	+1.2	10	6,365	nw.	42	nw.	5	7	14	9	.....	7.8	0.0
Yankton	1,233	49	57	28.54	29.87	−.08	50.4	+2.5	88	4	62	22	1	39	42	.....	.....	.....	3.20	+0.4	9	5,747	e.	33	nw.	7	6	14	10	6.2	2.6	0.0

TABLE 1.—*Climatological data for Weather Bureau stations, April, 1929*—Continued

District and station	Elevation of instruments: Barometer above sea level	Elevation of instruments: Thermometer above ground	Elevation of instruments: Anemometer above ground	Pressure: Station reduced to mean of 24 hours	Pressure: Sea level, reduced to mean of 24 hours	Pressure: Departure from normal	Temperature of the air: Mean max. + mean min. ÷2	Temperature of the air: Departure from normal	Temperature of the air: Maximum	Temperature of the air: Date	Temperature of the air: Mean maximum	Temperature of the air: Minimum	Temperature of the air: Date	Temperature of the air: Mean minimum	Temperature of the air: Greatest daily range	Mean wet thermometer	Mean temperature of the dew-point	Mean relative humidity	Precipitation: Total	Precipitation: Departure from normal	Precipitation: Days with 0.01, or more	Wind: Total movement	Wind: Prevailing direction	Wind: Maximum velocity: Miles per hour	Wind: Maximum velocity: Direction	Wind: Maximum velocity: Date	Clear days	Partly cloudy days	Cloudy days	Average cloudiness, tenths	Total snowfall	Snow, sleet, and ice on ground at end of month
	Ft.	*Ft.*	*Ft.*	*In.*	*In.*	*In.*	*° F.*	*° F.*	*° F*		*° F*	*° F.*	*° F*	*° F*	*%*	*In.*	*In.*		*Miles*											*0–10*	*In.*	*In.*
Northern Slope							41.5	−1.7										60	2.40	+0.8										6.3		
Billings	3,140	5					44.5		78	28	60	17	6	29	49				0.50		7		nw.				7	9	14		T.	0.0
Havre	2,505	11	44	27.25	29.91	−0.02	40.6	−3.1	69	28	53	14	7	28	40	34	25	60	0.69	−0.3	6	4,865	sw.	33	sw.	2	2	12	16	7.0	3.1	0.0
Helena	4,110	87	112	25.68	29.91	−.06	38.8	−4.7	66	27	49	6	6	28	34	32	23	58	1.03	−0.1	9	5,559	sw.	31	sw.	15	1	10	19	7.5	16.3	0.0
Kalispell	2,973	48	56	26.80	29.88	−.08	40.4	−3.2	71	27	50	21	6	31	33	33	24	57	0.64	−0.2	6	4,315	nw.	28	w.	2	7	13	10	5.9	0.1	0.0
Miles City	2,371	48	55	27.35	29.92	−.04	44.7	0.0	74	28	56	16	11	33	41	37	27	57	0.70	−0.4	9	4,804	s.	34	nw.	29	6	14	10	6.0	2.6	0.0
Rapid City	3,259	50	58	26.47	29.90	−.05	44.4	+0.1	76	29	55	18	1	33	40	37	28	57	3.48	+1.4	9	5,722	n.	35	n.	24	6	14	10	5.9	19.3	0.0
Cheyenne	6,088	84	101	23.86	29.86	−.05	39.6	−1.3	65	3	50	19	25	30	31	32	25	61	4.79	+2.8	8	9,102	w.	48	sw.	5	7	10	13	6.1	15.5	T.
Lander	5,372	60	68	24.50	29.87	−.07	40.4	−2.0	67	28	51	14	7	30	38	33	26	63	4.27	+2.2	11	4,820	w.	50	sw.	5	12	11	7	5.1	19.5	T.
Sheridan	3,790	10	47	25.96	29.88		41.2		74	28	54	18	11	29	40	34	26	62	3.12	+1.2	10	4,087	nw.	32	sw.	4	6	15	9	6.0	9.8	0.0
Yellowstone Park	6,241	11	48	23.73	29.90	−.06	34.0	−3.0	58	28	43	13	10	25	29	29	22	66	1.48	0.0	14	6,147	sw.	29	sw.	28	3	4	23	7.9	9.8	0.1
North Platte	2,821	11	51	26.91	29.83	−.09	50.4	+1.8	84	4	63	21	1	38	50	41	33	62	3.83	+1.8	10	5,867	nw.	36	n.	24	13	7	10	5.2	T.	0.0
Middle Slope							53.3	+1.8										60	3.16	+0.6										5.3		
Denver	5,292	106	113	24.58	29.84	−.06	46.6	−0.5	76	3	57	20	8	36	34	37	26	52	1.69	−0.4	9	5,369	s.	31	n.	24	10	14	6	5.1	6.5	0.0
Pueblo	4,685	80	86	25.14	29.80	−.08	51.0	+0.9	80	17	66	21	1	36	47	38	23	40	0.78	−0.5	3	5,406	nw.	36	w.	23	9	15	6	5.0	0.0	0.0
Concordia	1,392	50	58	28.39	29.86	−.07	55.9	+2.4	90	4	67	22	1	45	44	48	42	68	5.09	+2.7	14	6,544	s.	35	sw.	5	6	13	11	6.2	0.0	0.0
Dodge City	2,509	11	51	27.27	29.86	−.04	56.6	+3.0	90	4	70	24	1	43	39	46	39	62	1.67	−0.3	8	7,829	nw.	36	nw.	24	15	9	6	4.2	0.0	0.0
Wichita	1,358	139	158	28.41	29.83	−.10	58.4	+2.0	84	3	68	28	1	49	32	52	46	70	4.04	+1.1	9	9,607	s.	43	sw.	5	8	12	10	5.7	0.0	0.0
Broken Arrow	765	11	56	29.06	29.88		61.4		83	4	71	35	1	52	30				6.79	+3.1	10	9,900	s.	38	s.	6	7	13	10	6.2	0.0	0.0
Oklahoma City	1,214	10	47	28.59	29.85	−.07	63.1	+3.3	87	30	74	35	1	52	30	54	48	65	2.08	−1.2	7	7,742	s.	27	w.	24	12	9	9	4.9	0.0	0.0
Southern Slope							65.9	+3.1										52	0.59	−1.2										4.4		
Abilene	1,738	10	52	28.08	29.86	−.04	68.4	+4.0	91	30	80	42	11	57	33	55	44	53	1.18	−1.5	7	8,221	s.	33	s.	6	11	4	15	5.4	0.0	0.0
Amarillo	3,676	10	49	26.15	29.84	−.03	60.0	+4.2	84	3	74	33	11	46	38	49	42	61	T.	−1.8	0	6,974	sw.	25	s.	23	19	8	3	3.3	0.0	0.0
Del Rio	944	64	71	28.85	29.82	−.07	74.7	+4.1	98	30	85	56	15	65	33	63	55	57	1.17	−0.6	4	6,442	se.	35	nw.	7	7	13	10	5.9	0.0	0.0
Roswell	3,566	75	85	26.24	29.80	−.05	60.6	0.0	85	3	76	32	11	45	43	45	27	35	T.	−0.9	0	6,365	s.	32	sw.	23	18	7	5	3.2	0.0	0.0
Southern Plateau							56.8	−0.5										35	0.12	−0.3										2.7		
El Paso	3,778	152	175	26.08	29.81	−.02	64.9	+1.5	89	4	79	44	11	51	34	44	17	20	T.	−0.3	0	8,215	w.	40	w.	9	18	12	0	2.5	0.0	0.0
Santa Fe	7,013	38	53	23.14	29.81	−.03	47.1	+0.4	71	17	59	23	11	35	34	34	16	33	0.15	−0.8	2	5,308	sw.	31	sw.	23	12	11	7	4.6	T.	0.0
Flagstaff	6,907	10	59	23.25	29.82	−.02	40.8	−1.3	68	16	55	15	7	27	40	33		59	1.65		4		sw.		sw.	22	9	16	5		T.	0.0
Phoenix	1,108	10	107	28.71	29.86	−.01	66.2	−0.8	91	30	81	39	7	52	38	48	28	29	0.43	0.0	1	3,979	w.	19	sw.	22	21	4	5	2.4	0.0	0.0
Yuma	141	9	54	29.73	29.88	−.01	67.2	−2.3	95	30	83	38	8	51	42	51	33	34	T.	−0.1	0	3,644	w.	26	nw.	4	26	2	2	1.2	0.0	0.0
Independence	3,957	6	27	25.88	29.90	.00	54.4	−0.7	84	16	69	24	7	40	42	38			0.00	−0.1	0		nw.				13	12	5		0.0	0.0
Middle Plateau							44.7	−3.7										52	1.40	+0.4										5.6		
Reno	4,532	74	81	25.39	29.95	−.02	43.6	−3.7	72	27	56	15	7	31	43	35	24	52	0.66	+0.2	5	5,529	w.	30	w.	28	10	11	9	5.0	6.8	0.0
Tonopah	6,090	12	20				42.2		70	16	51	15	6	33	27	33	20	44	0.22		5		nw.									
Winnemucca	4,344	18	56	25.54	29.94	−.02	42.2	−4.5	72	16	56	12	6	28	47	35	27	62	0.93	+0.1	9	5,203	sw.	30	nw.	8	9	20	1	4.8	3.5	0.0
Modena	5,473	10	43	24.49	29.83	−.05	42.2	−3.8	75	16	57	7	7	28	47	32	19	50	0.99	+0.1	8	7,756	w.	50	s.	3	8	12	10	5.4	4.8	0.0
Salt Lake City	4,360	163	203	25.50	29.87	−.05	46.4	−3.2	71	16	55	22	7	38	29	38	29	57	3.97	+1.9	12	5,148	s.	33	nw.	5	6	9	15	6.7	19.0	0.0
Grand Junction	4,602	60	68	25.26	29.82	−.06	49.2	−3.2	77	17	61	24	10	38	35	38	24	44	0.49	−0.3	11	4,890	n.	34	sw.	6	5	14	11	6.0	1.2	0.0
Northern Plateau							45.9	−3.4										58	1.30	+0.1										6.4		
Baker	3,471	48	53	26.36	29.96	−.04	40.2	−5.0	71	27	51	17	6	29	36	35	27	63	1.12	0.0	10	4,607	se.	21	nw.	22	6	6	18	6.9	2.0	0.0
Boise	2,739	78	86	27.08	29.95	−.03	46.8	−3.6	73	27	57	24	10	37	35	40	33	64	1.28	+0.1	12	3,887	se.	25	nw.	23	4	8	18	7.2	1.1	0.0
Lewiston	757	40	48	29.13	29.94	−.05	49.8	−3.1	80	27	60	27	1	39	37				1.08	0.0	10	3,105	e.	25	nw.	3	9	7	14	6.2	T.	0.0
Pocatello	4,477	60	68	25.34	29.87	−.07	43.4	−2.6	69	16	52	24	7	34	32	35	27	57	2.61	+1.2	15	5,973	sw.	33	sw.	9	3	12	15	7.0	16.5	0.0
Spokane	1,929	101	110	27.87	29.93	−.06	45.0	−3.4	73	26	55	25	9	35	39	37	28	57	1.14	0.0	11	4,466	s.	24	sw.	14	10	9	11	5.4	2.8	0.0
Walla Walla	991	57	65	28.87	29.95	−.06	50.2	−2.8	75	26	60	32	1	41	31	41	30	50	0.57	−0.9	4	4,011	s.	26	w.	14	8	10	12	5.7	4.0	0.0
North Pacific Coast Region							46.3	−2.8										72	3.06	+0.2										7.1		
North Head	211	11	53	29.80	30.03	−.02	44.6	−2.9	63	18	49	33	5	41	19	43	41	90	4.66	+0.5	20	10,355	n.	56	sw.	16	3	10	17	6.9	0.4	0.0
Port Angeles	29	8	53				43.8		60	23	51	30	8	36	22				2.20	+0.2	13	4,050	sw.	29	w.	29	5	10	15		0.7	0.0
Seattle	125	215	250	29.85	29.98	−.05	46.7	−2.7	66	26	54	34	5	40	25	42	37	73	1.59	−0.8	15	6,249	s.	38	sw.	15	6	8	16	6.6	T.	0.0
Tacoma	194	172	201	29.79	30.00	−.03	46.4	−3.3	68	26	54	30	6	38	27				3.22	+0.4	17	5,971	w.	41	sw.	15	2	15	13	6.7	3.0	0.0
Tatoosh Island	86	9	53	29.87	29.97	−.03	44.3	−1.8	56	18	48	34	4	41	14	43	41	89	5.54	−0.1	22	9,164	w.	60	s.	16	2	4	24	8.2	0.6	0.0
Yakima	1,076	58	67	28.78	29.93		49.0		80	26	60	26	8	38	38	39	26	45	0.09	−0.4	3	4,431	nw.	32	w.	14	10	10	10	5.4	T.	0.0
Medford	1,425	4	80	28.48	30.00		47.6		79	26	60	27	1	36	43	41	34	67	1.54		13		n.	23	sw.	8	4	7	19	7.6	1.8	0.0
Portland, Oreg.	153	68	106	29.86	30.01	−.05	49.2	−2.6	75	25	57	33	5	41	30	44	38	70	4.06	+1.2	18	3,983	nw.	24	sw.	15	2	10	18	7.8	T.	0.0
Roseburg	510	75	99	29.48	30.04	−.03	47.7	−3.3	76	26	57	30	5	38	36	42	37	72	3.15	+0.9	18	2,764	sw.	20	w.	4	4	7	19	7.4	0.2	0.0
Middle Pacific Coast Region							53.1	−2.6										72	1.22	−0.6										5.2		
Eureka	62	73	89	30.03	30.10	−.01	48.2	−1.7	62	18	54	32	6	43	21	46	44	85	2.61	−0.7	16	4,297	n.	22	w.	4	3	10	17	7.5	T.	0.0
Red Bluff	330	54	58	29.64	30.00	−.03	55.8	−3.2	86	26	68	31	6	43	37	47	37	56	1.12	−0.6	7	4,193	s.	25	nw.	8	9	9	12	5.4	T.	0.0
Sacramento	69	106	117	29.94	30.01	.00	54.4	−3.7	82	26	66	34	6	43	32	49	43	69	0.44	−1.1	6	5,272	s.	23	sw.	8	19	6	5	3.2	0.0	0.0
San Francisco	155	208	243	29.88	30.66	+.01	53.4	−1.6	71	1	59	40	6	47	25	48	45	77	1.01	−0.6	8	6,035	w.	36	nw.	4	9	16	6	5.4	0.0	0.0
San Jose	141	12	110	29.92	30.07		53.7	−3.0	75	25	65	32	7	42	35				0.92	−0.2	6	4,228	nw.	24	sw.	2	10	14	6	4.7	0.0	0.0
South Pacific Coast							57.4	−2.0										69	1.08	+0.1										4.5		
Fresno	327	89	98	29.66	30.02	+.03	57.2	−3.0	82	26	70	34	7	45	34	48	39	58	0.69	−0.3	5	4,726	nw.	24	nw.	30	13	15	2	3.6	0.0	0.0
Los Angeles	338	159	191	29.66	30.02	+.03	57.4	−2.0	85	15	65	42	7	50	33	51	46	72	1.99	+1.0	4	3,735	sw.	17	sw.	8	10	13	7	4.7	0.0	0.0
San Diego	87	62	70	29.93	30.02	+.03	57.5	−1.0	75	15	63	41	7	52	24	52	49	76	0.57	−0.2	4	4,612	w.	26	s.	4	8	14	8	5.3	0.0	0.0
West Indies																																
San Juan, P. R.	82	9	54	29.92	30.01		76.2	−0.4	89	16	82	66	10	71	17				1.34	−2.5	15	8,893	e.	32	e.	2	9	20	1	4.5	0.0	0.0
Panama Canal																																
Balboa Heights	118	7	97	[1] 29.76	[2] 29.84	+.01	81.6	0.0	93	30	90	72	12	74	21			[2] 76	0.43	−2.3	5	5,681	n.	24	n.	5	0	12	18	7.6	0.0	0.0
Cristobal	38	7	97	[1] 29.83	[2] 29.86	.00	82.2	+0.4	89	16	87	73	11	77	15	76	74	[2] 78	0.67	−3.6	11	9,164	n.	31	n.	4	2	17	11	6.7	0.0	0.0
Alaska																																
Juneau	80	11	50	[1] 29.84	[1] 29.94		38.0		59	22	46	13	3	30	27	33	26	64	3.34		14	4,674	e.	25	w.	1	7	8	15	6.0	8.8	0.0
Hawaiian Islands																																
Honolulu	38	86	100	[1] 30.04	[1] 30.08		74.5		82	30	79	67	13	70	12	67	63	70	0.80	−1.3	8	6,085	e.	29	e.	11	13	9	8	5.0	0.0	0.0

[1] Pressure not reduced to mean of 24 hours.

[2] Observations taken hourly.

TABLE 2.—*Data furnished by the Canadian Meterological Service, April, 1929*

Stations	Altitude above mean sea level, Jan. 1, 1919	Pressure			Temperature of the air						Precipitation		
		Station reduced to mean of 24 hours	Sea level reduced to mean of 24 hours	Departure from normal	Mean max. + mean min. ÷ 2	Departure from normal	Mean maximum	Mean minimum	Highest	Lowest	Total	Departure from normal	Total snow fall
	Feet	*Inches*	*Inches*	*Inches*	°*F.*	°*F.*	°*F.*	°*F.*	°*F.*	°*F.*	*Inches*	*Inches*	*Inches*
Cape Race, N. F	99				31.7		38.2	25.3	45	10	4.88		0.7
Sydney, C. B. I	48												
Halifax, N. S	88												
Yarmouth, N. S	65												
Charlottetown, P. E. I	38												
Chatham, N. B	28												
Father Point, Que	20												
Quebec, Que	296	29.58	29.91	−0.08	35.6	+0.5	41.9	29.3	61	15	3.52	+1.43	11.9
Doucet, Que	1,236				29.5		40.3	18.7	55	0	0.39		2.4
Montreal, Que	187	29.66	29.87	−.13	40.8	+1.1	48.3	33.2	63	14	5.41	+3.17	11.0
Ottawa, Ont	236	29.62	29.89	−.13	41.8	+1.8	51.0	32.6	69	11	3.83	+2.33	10.2
Kingston, Ont	285	29.57	29.89	−.13	42.6	+2.6	49.8	35.5	67	15	3.59	+1.80	0.1
Toronto, Ont	379	29.48	29.89	−.13	45.6	+4.8	53.7	37.5	74	21	6.21	+3.84	0.1
Cochrane, Ont	930				32.2		41.2	23.2	64	−6	1.05		6.1
White River, Ont	1,244	28.59	29.93	−.11	33.6	+0.6	45.1	22.2	63	0	2.20	+0.95	5.0
London, Ont	808				46.3		55.6	37.0	81	20	5.50		1.0
Southampton, Ont	656	29.19	29.92	−.11	41.5	+2.8	49.1	33.9	70	16	7.71	+5.91	2.2
Parry Sound, Ont	688	29.19	29.89	−.13	40.0	+2.4	48.9	31.2	67	5	3.46	+1.55	5.2
Port Arthur, Ont	644	29.23	29.95	−.08	37.2	+3.7	45.6	28.8	59	18	1.34	−0.38	0.4
Winnipeg, Man	760												
Minnedosa, Man	1,690	28.08	29.93	−.08	36.0	0.0	47.0	25.0	68	2	1.81	+0.75	4.6
Le Pas, Man	860				31.3		42.2	20.4	59	0	0.85		4.2
Qu'Appelle, Sask	2,115	27.63	29.91	−.08	35.6	−1.8	45.3	25.8	61	1	0.73	−0.32	5.9
Moose Jaw, Sask	1,759				38.3		50.5	26.1	65	7	0.32		3.0
Swift Current, Sask	2,392	27.31	29.86	−.10	37.4	−3.9	49.7	25.0	65	−4	0.62	−0.31	4.7
Medicine Hat, Alb	2,144												
Calgary, Alb	3,428												
Banff, Alb	4,521												
Prince Albert, Sask	1,450	28.37	29.98	.00	32.8	−3.3	42.2	23.5	66	−8	2.63	+1.80	18.5
Battleford, Sask	1,592	28.16	29.93	−.04	34.0	−3.2	44.9	23.2	74	−6	0.42	−0.05	1.7
Edmonton, Alb	2,150												
Kamloops, B. C	1,262												
Victoria, B. C	230	29.71	29.96	−.05	45.9	−0.9	51.9	40.0	60	34	1.13	−1.24	0.4
Barkerville, B. C	4,180												
Estevan Point, B. C	20												
Prince Rupert, B. C	170												
Hamilton, Ber	151												

Chart I. Departure (°F.) of the Mean Temperature from the Normal, April, 1929

Chart I. Departure (°F.) of the Mean Temperature from the Normal, April, 1929

April, 1929. M. W. R.

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Chart II. Tracks of Centers of Anticyclones, April, 1929. (Inset) **Departure of Monthly Mean Pressure from Normal**

(Plotted by Gordon E. Dunn)

Chart III. Tracks of Centers of Cyclones, April, 1929. (Inset) **Change in Mean Pressure from Preceding Month**

(Plotted by Gordon E. Dunn)

Chart III. Tracks of Centers of Cyclones, April, 1929. (Inset) Change in Mean Pressure from Preceding Month

(Plotted by Gordon E. Dunn)

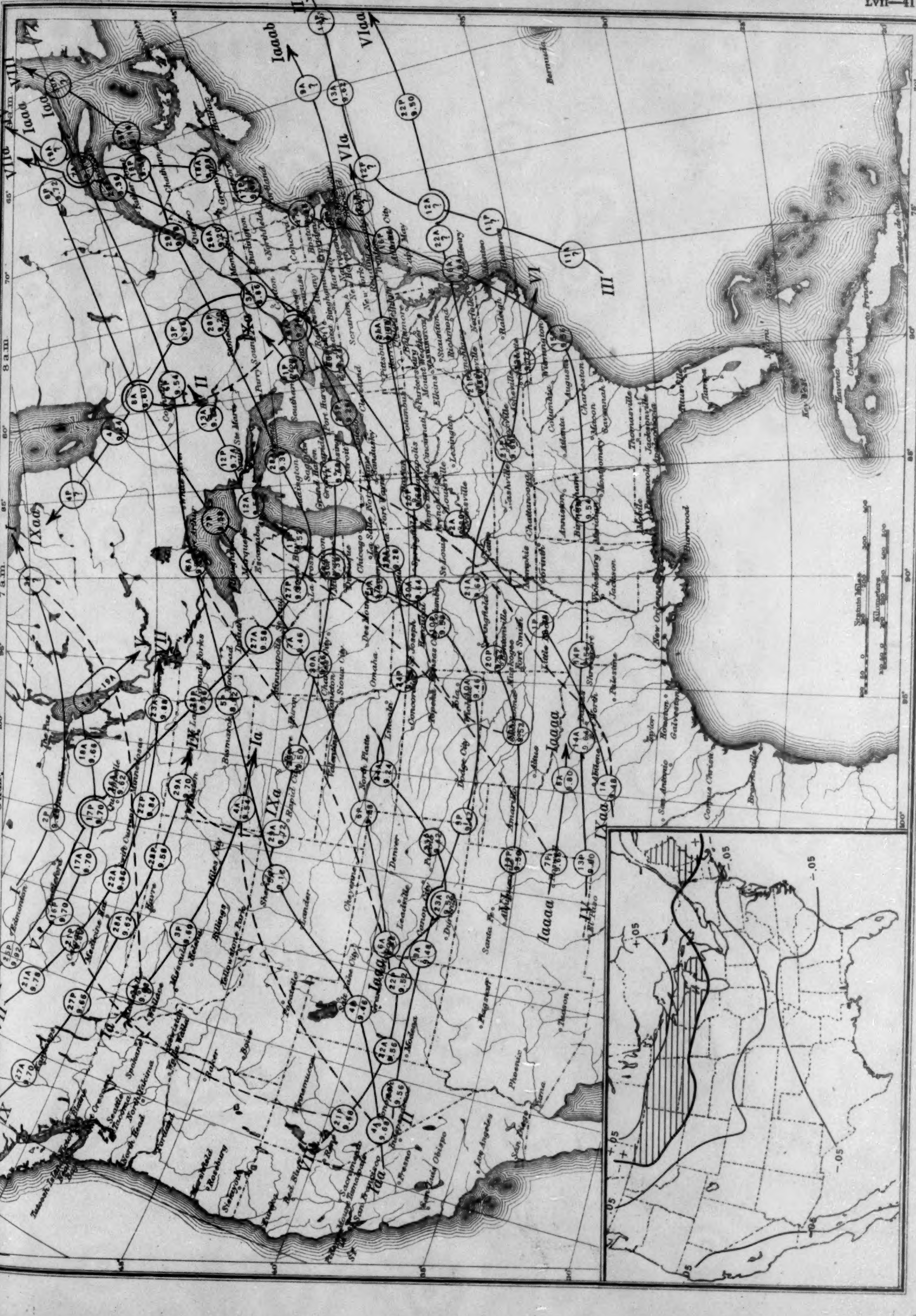

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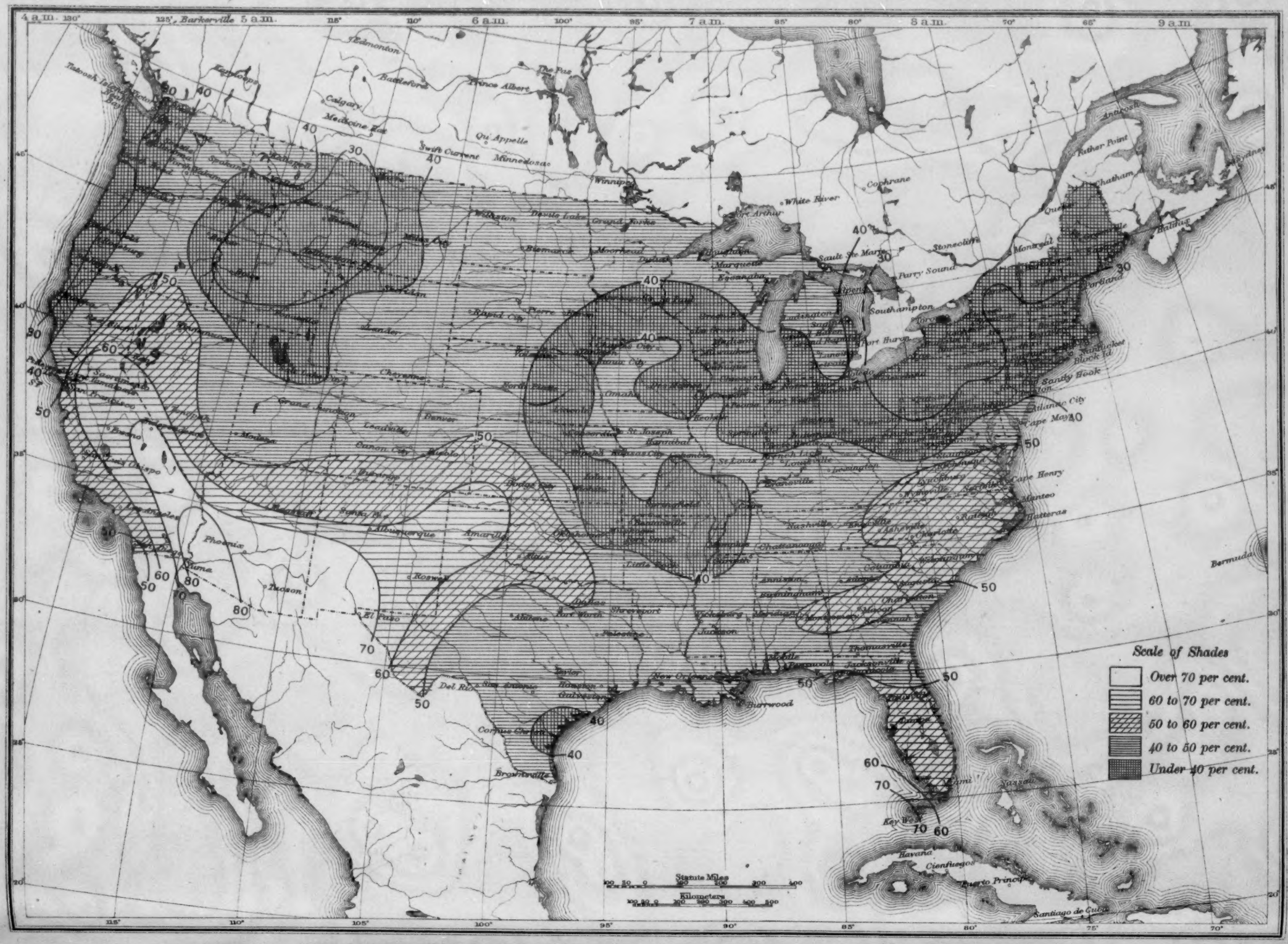
Chart IV. Percentage of Clear Sky between Sunrise and Sunset, April, 1929



April, 1929. M. W. R.

Chart V. Total Precipitation, Inches, April, 1929. (Inset) Departure of Precipitation from Normal

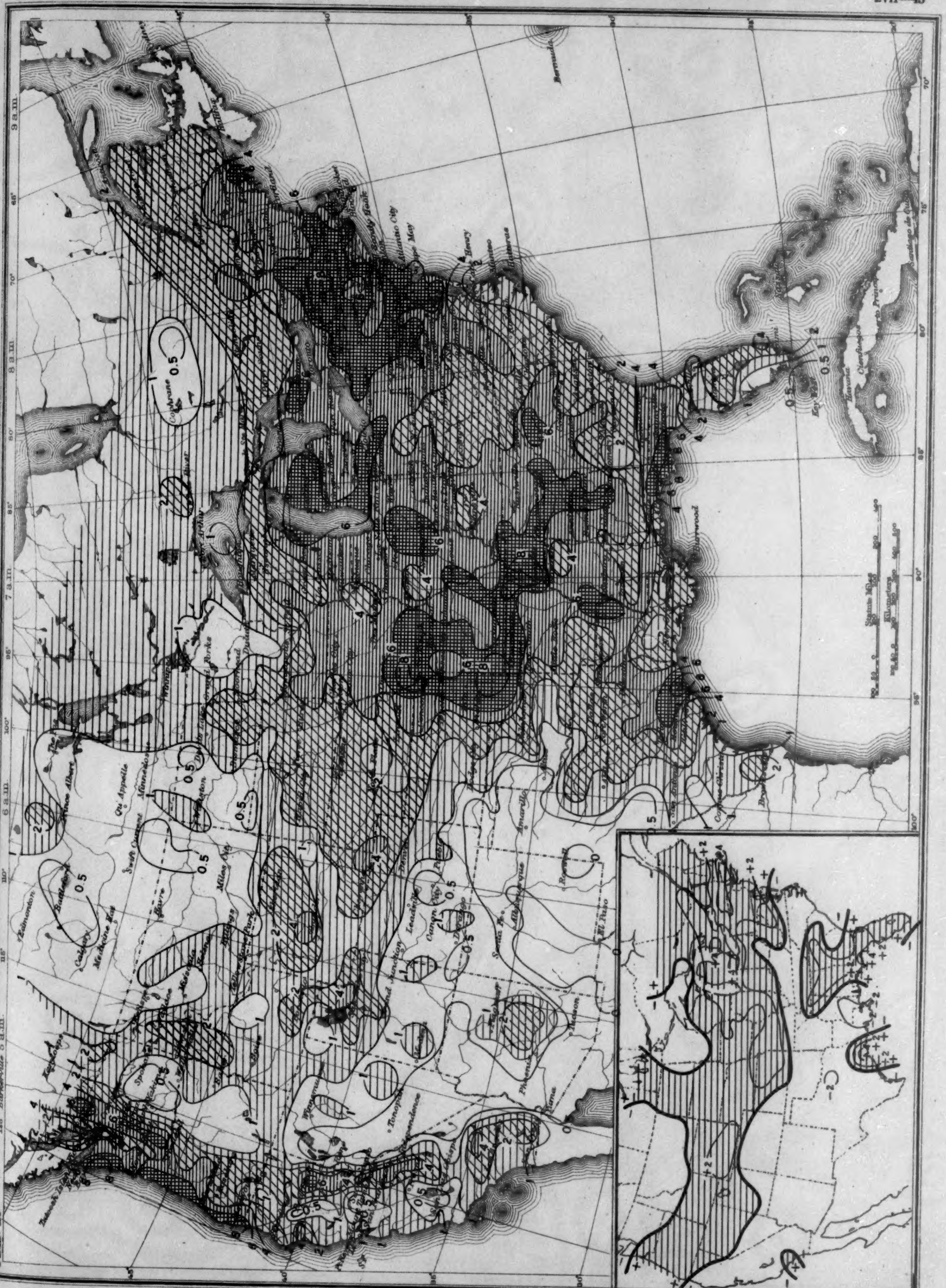


Chart V. Total Precipitation, Inches, April, 1929. (Inset) Departure of Precipitation from Normal

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Chart VI. Isobars at Sea level and Isotherms at Surface; Prevailing Winds, April, 1929

Chart VII. Total Snowfall, Inches, April, 1929.

Chart VII. Total Snowfall, Inches, April, 1929.

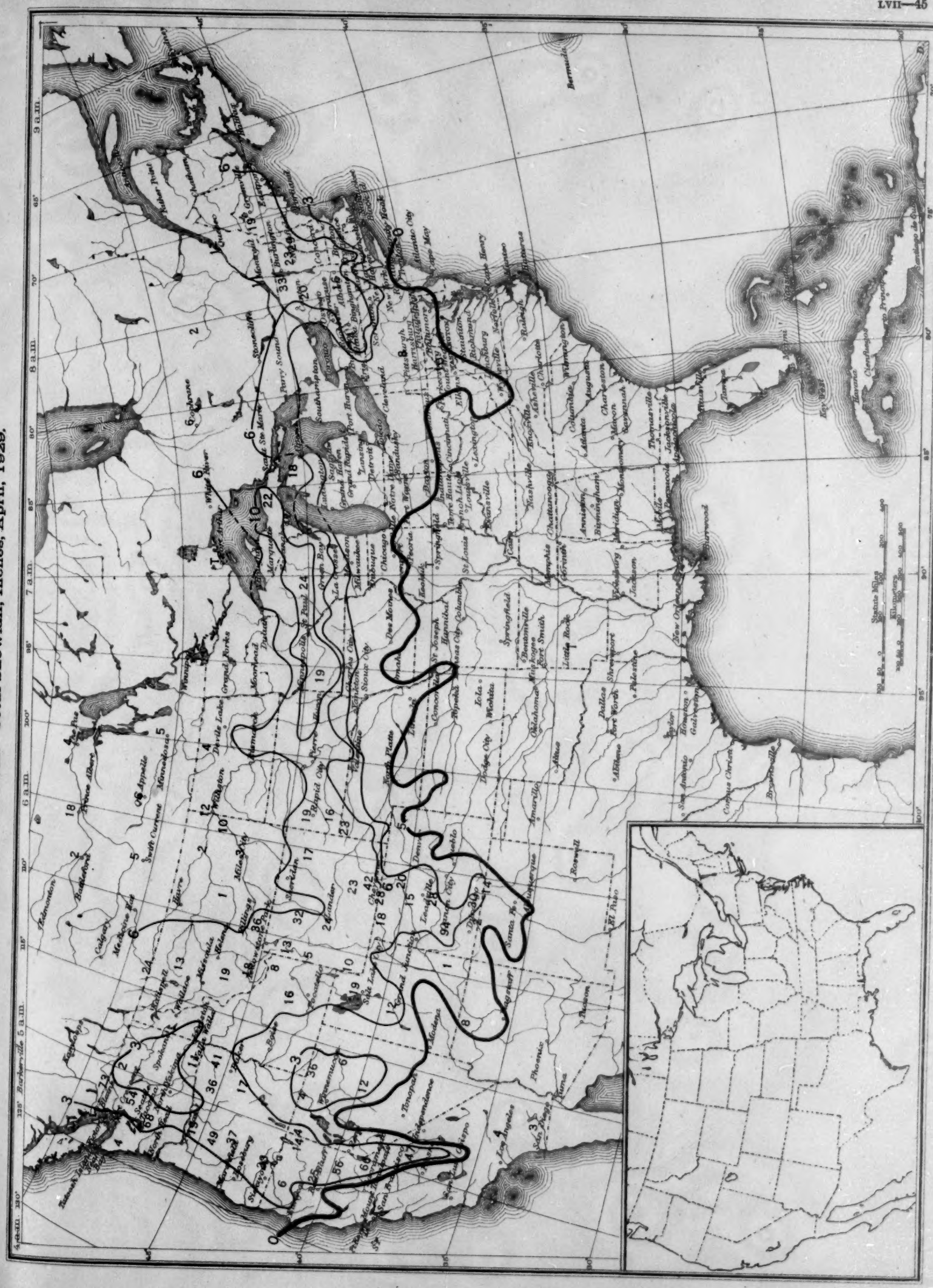

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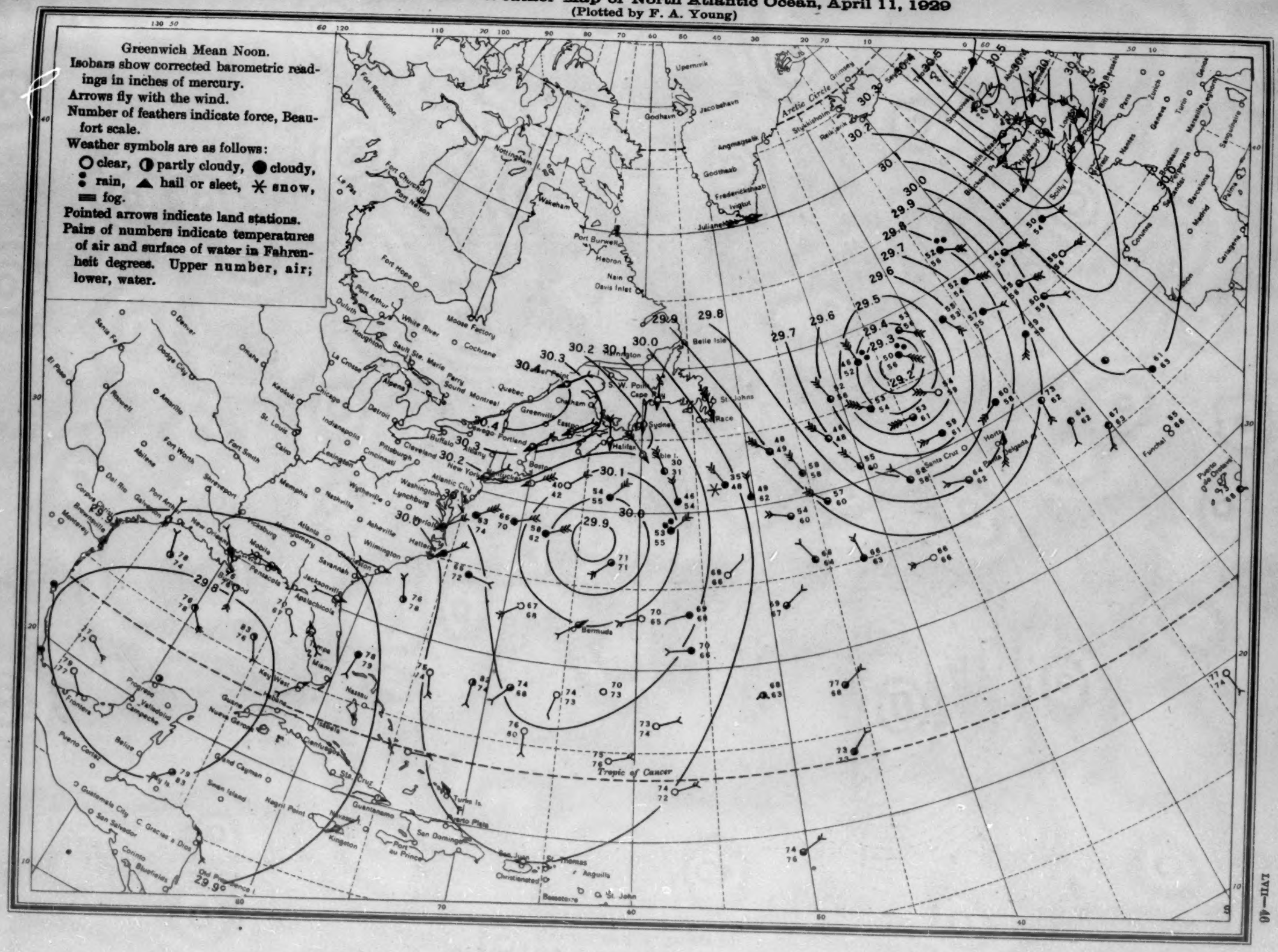
Chart VIII. Weather Map of North Atlantic Ocean, April 11, 1929
(Plotted by F. A. Young)

Chart VIII. Weather Map of North Atlantic Ocean, April 11, 1929

(Plotted by F. A. Young)



April, 1929. M. W. R.

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Chart IX. Weather Map of North Atlantic Ocean, April 12, 1929
(Plotted by F. A. Young)

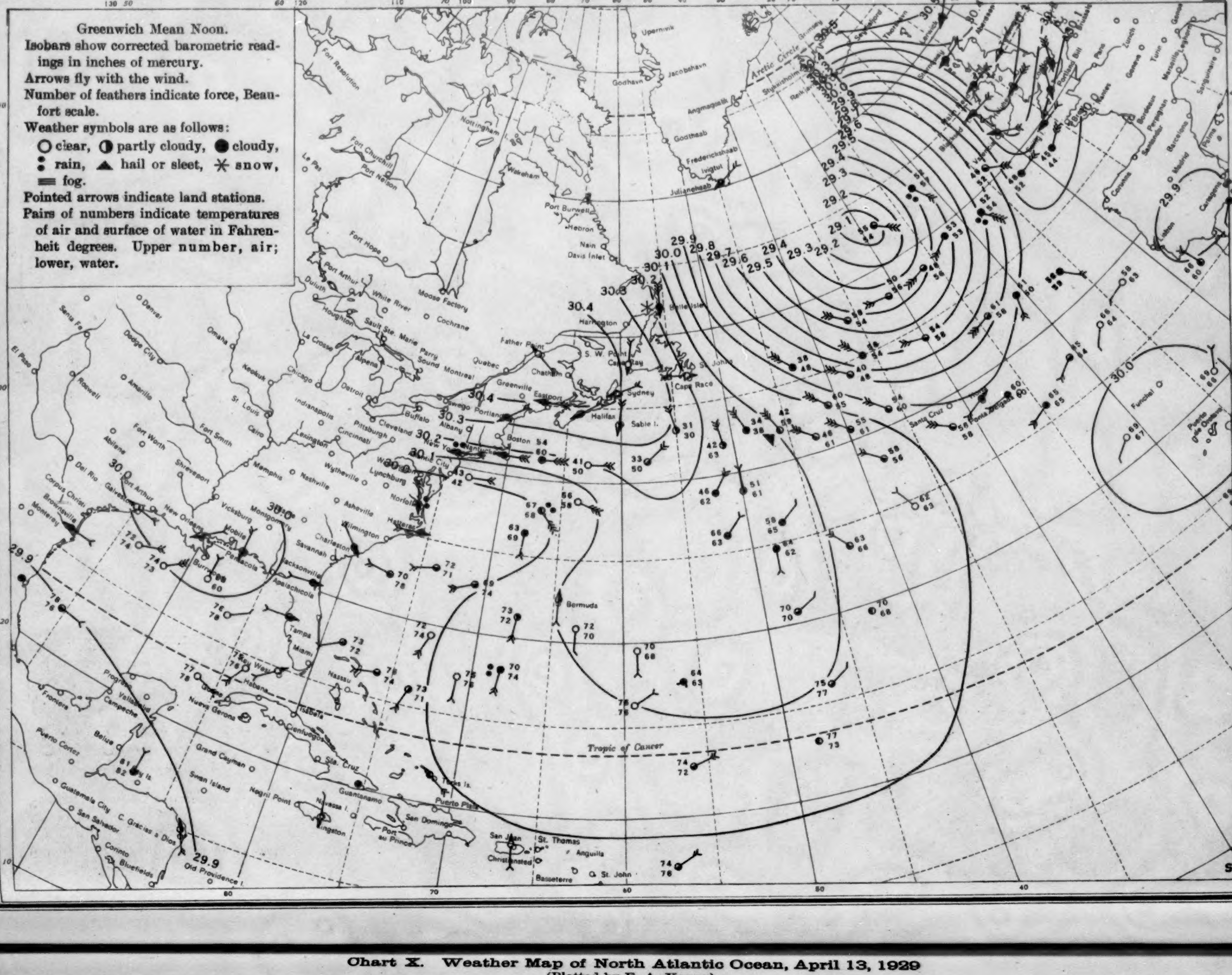

Chart X. Weather Map of North Atlantic Ocean, April 13, 1929
(Plotted by F. A. Young)

Chart X. Weather Map of North Atlantic Ocean, April 13, 1929

(Plotted by F. A. Young)

Greenwich Mean Noon.

Isobars show corrected barometric readings in inches of mercury.

Arrows fly with the wind.

Number of feathers indicate force, Beaufort scale.

Weather symbols are as follows:

○ clear, ◑ partly cloudy, ● cloudy, • rain, ▲ hail or sleet, ✳ snow, ≡ fog.

Pointed arrows indicate land stations.

Pairs of numbers indicate temperatures of air and surface of water in Fahrenheit degrees. Upper number, air; lower, water.

Arctic Circle

Tropic of Cancer

April, 1929. M. W. R.

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Chart XI. Weather Map of North Atlantic Ocean, April 14, 1929

(Plotted by F. A. Young)

Greenwich Mean Noon.

Isobars show corrected barometric readings in inches of mercury.

Arrows fly with the wind.

Number of feathers indicate force, Beaufort scale.

Weather symbols are as follows:

○ clear, ◑ partly cloudy, ● cloudy, ⁚ rain, ▲ hail or sleet, ✳ snow, ═ fog.

Pointed arrows indicate land stations.

Pairs of numbers indicate temperatures of air and surface of water in Fahrenheit degrees. Upper number, air; lower, water.